# THE HUMAN BODY
# AND ITS FUNCTIONS

# The Human Body

BY

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DEDICATED
TO ALL WHO ARE PASSING FROM CHILDHOOD TO YOUTH AND TO ALL OLDER FOLK WHO MISSED THIS KNOWLEDGE WHEN THEY WERE YOUNG

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# THE HUMAN BODY.

## CHAPTER I.

### *Individual Units.*

WE human beings always think of ourselves as whole individuals. This is of course natural, for the mere idea of a half or less of a human being creates in us a sense of the horror of accident and death. A dismembered human being is no longer able to play his part in this world.

Beneath each of our skins dwells, compact, alert, vital, all that each one of us feels to be " I." The " I " is a very self-conscious definite unit, a life, a single active centre which wills and does, so that each human being feels (although he may be too mock-modest to say) " I and the Universe " !

Yet beneath our skins progress the careers of countless tiny individuals quite unlike " ourselves." We depend on the products of the life-activities of innumerable small centres who live with such rich variety, such marvellous precision, and such wonderfully combined results, that " our own " skins smoothing over our bodies are merely an opaque covering hiding immeasurably complex machinery.

As a child springs up in its play, jumping off the ground to catch a ball, it moves with the easiest, lythest grace. Those movements are so spontaneous that the child is almost unconscious that he is exerting any judgment or

will in his play, and quite unconscious that he is controlling multitudes of lives more autocratically than any despot ever controlled his subjects. Yet if that unit of humanity we call a child did not have at work inside his body, underneath his skin an army of reliable though invisibly minute units, on whose energies he can call, whose processes he commands, he would not be able to catch the flying ball.

A human body has often been compared with a machine. It is better perhaps to compare it with a large number of machines, working together at close quarters, and in a marvellously adjusted harmony, acting and re-acting upon each other so subtly that to know all about each of the mere parts of the machinery would not tell us much of the secrets of their combined power. To compare the human body with a machine, however, simplifies it far too much, and thus does not convey a very correct idea of the way it is built. In a machine the various parts, the piston, the wheels and all the adjusted structures are made of wood or metal and have each no life nor power in themselves: in the human body, all the parts are made of countless thousands of very tiny *living* units. Each cell, although necessary to the work of the body as a whole, leads its own little life on its own lines, requiring nourishment and the right kind of environment in which to live that life. A single human body may perhaps more correctly be described as a community of an immense number of individuals living together and resulting in a super-unit of power to which they all contribute—that is the human life.

Although each cell-unit lives its own minute, separate and peculiar life, each also lives in some definite minor group or community, for each is adapted to perform a duty of importance to the great super-unit, the human life as a whole. For instance, each human body has only one liver, and this is a large mass of substance of a definite shape, size and weight. Considered as though our eyes could see as much as a strong microscope it is more like a city packed closely, with all its minute inhabitants specialised for one definite industry. It is permeated by its thoroughfares and channels—its great arterial system in a sense to be compared with our main roads, although in the body even the channels of the arterial system are also made of living cells.

In all living bodies the component communities are related so that the work of the whole is done by a division of labour. The special cells which do the various kinds of work performed by each of the "organs" such as liver, lungs or heart, live together in and compose the liver, lungs or heart. Similarly all the cells that do the work of muscle dwell in a large number of well-organised and well-arranged communities of muscles.

Then in addition to these specialised, though minute individuals working in their definitely appointed places on their tasks, there are cells which wander about the body. These roam, not freely or for their own amusement, but on altruistic service. One type of such cells are the red corpuscles in the blood drifting round the arterial channels, which carry the necessary oxygen from the outer air round to all the workers in the indus-

tries within the body. In addition to the wandering cells, and the fixed communities of industrial cells as we may call the various important organs, the human unit possesses an elaborate system of messenger cells. These are arranged along slender lines of communication, and we call them nerves. There is also a system of central government in the cells of the brain and the higher nervous centres.

Any one human being who laughs and plays, who has his own busy work in our human community, who enjoys the beauty of the world, and who can through his imagination begin to feel, although he cannot understand, the beauty of the heavens and the great cosmos beyond, derives his power, indeed owes his very existence to these invisible unit cells, all living in communities ceaselessly active, some of them working day and night for the whole span of that human being's life. All of the microscopic units work out not only their own lives, but contribute to the composite life of the community which is vast in comparison with themselves—that one little human life which we know as a living baby, a school child or a man or woman of affairs.

A realisation of this marvellous complexity should always guide our considerations of our own bodies. Were I, however, to stress this aspect all the time while trying to explain in simple words the main features of our physiology, the account would be so insuperably complicated that it would not be possible to make it clear in many volumes. Hence for the purpose of this little book, and to give those who read it an unblurred

outline of the main features of a human body, I may often speak as though everything were much simpler than it really is. Without referring each time to the millions of little individual lives composing it, I may speak of bones and cartilage, of muscles and heart as though they themselves were simple things made of some uniform substance. This must not delude you into forgetting the marvellous richness of the complex lives of the cells composing each organ in any body. I hope also that you already realise enough of the chemical structure of matter to know that behind the living cells are again units of an even more infinitesimal order. There are phalanxes and armies of much more minute ultimate chemical molecules, atoms and electrons, and it is out of their complexity that the microscopic cell-units each builds its own minute but still more complex structure.

Behind the comparatively simple skin that rounds off the limits between our individual human bodies and the outer world, worlds within worlds of complexity and marvel are enwrapt.

## CHAPTER II.

### *General Architecture.*

OUR material bodies make it possible for each man or woman to take part in the intellectual and material activities of modern civilisation. These only originate as an expression of the activity of mankind. Yet the human body is very similar in many respects to that of other mammals such as rabbits, dogs, lions, tigers and monkeys. Even with the very lowliest animals man's body has something in common, for all animals are composed of living cell-units. By the careful study of the way the cells act, re-act and live their lives in animals' bodies much has been discovered about living tissue that it would have been dangerous or impossible to detect in mankind because of the difficulties which must surround the study of man's own internal organs.

It is true that the study of life, or Biology as it is called, is unfortunately not a part of the education of everyone. Nevertheless many thousands of young people do get some instruction in this science, yet, curiously enough, those who go to school and college are often taught most carefully a great deal about the bodies of animals, and nothing whatever, or very little, about their own bodies. For example elaborate detail is carefully described with accurate and beautiful diagrams

showing all the nerves, functions, and types of cells in such animals as the rabbit, the frog, and the dog fish, in that model text-book of Marshall and Hearsts on Elementary Zoology. Hundreds, indeed thousands of students in schools and colleges have studied every word and diagram in that book. Yet the majority of those students have been sent out into the world not only not knowing the same kind of detail about their own bodies, but instructed in next to nothing at all, and knowing only what they piece together by inference from what they learnt about those very remote animals. The ideas of the majority of human beings about their own bodies are either quite wrong or very hazy.

This is a strange state of affairs. Never would it have been tolerated by an intelligently regulated society, and it certainly will not be tolerated much longer. As a poet long ago most truly said " The proper study of mankind is man." It is far more important that we should know about the inner working of our own bodies than about those of the frog or the rabbit. Yet we ought certainly to study the frog and the rabbit because we can do so easily, and it is far more difficult to find out the details about ourselves. If chloroform is used quickly and kindly anyone can kill and dissect a frog so as to find out how its heart and veins run in its body, and see the position and structure of all its organs. We have to depend on dissections made by others for knowledge of our own bodies, for fortunately few of us have seen " their own insides " through operation or accident.

It is not possible for ordinary people to get such a

FIG. 1.—Front View of a Man (*Kimber and Gray*).

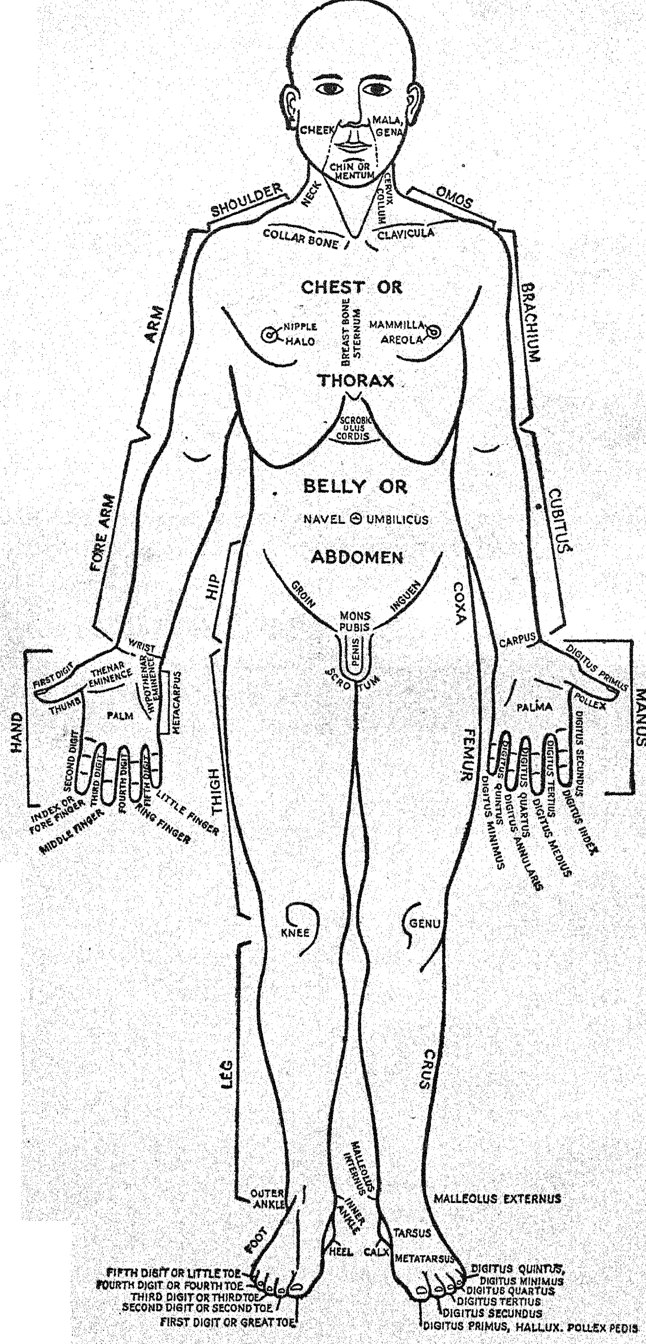
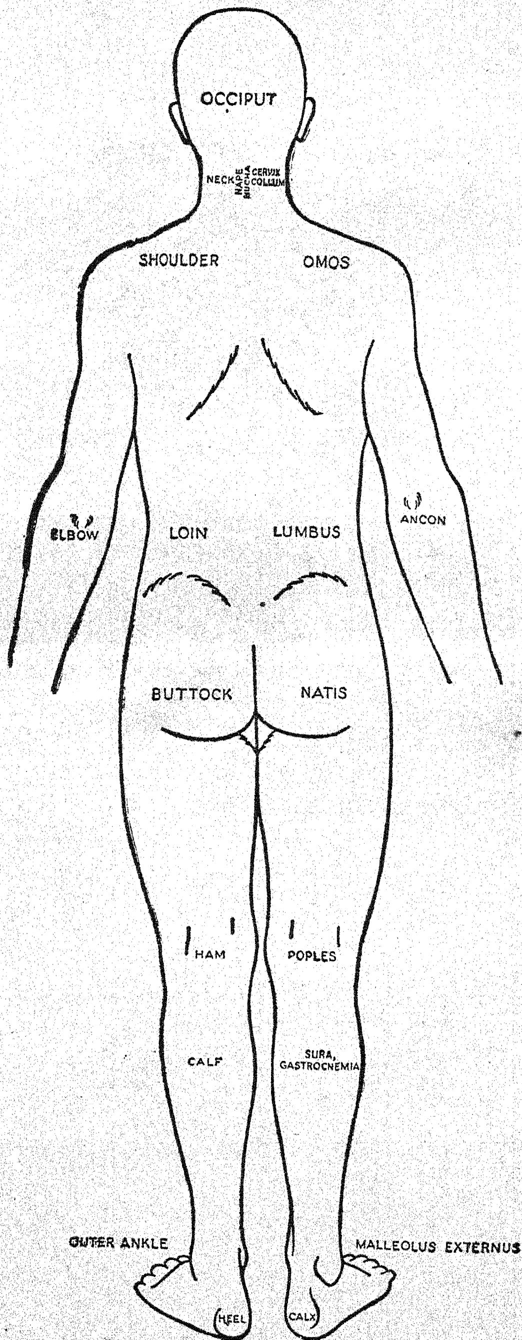


FIG. 2.—Back View of a Man (*Kimber and Gray*).



firsthand knowledge of human beings as any intelligent student can readily obtain about frogs or lower creatures. It is certain that most of those who read this book will never in the whole course of their lives be able to study the inside of a human body to illuminate their ideas about their own lives.

Let us, therefore, approach the human being from the outside and see how much we can observe in it for ourselves of the clues to its secrets. However similar in some internal respects to those of animals, the human body has its own characteristic shape.

There are three main divisions of the body:—The trunk or main part with soft masses of organs and hollows of various kinds: the four solid limbs attached, made of bones and muscles designed for *movement*: the head, with the most precious soft masses of all encased in a strong bone box and with the special organs placed partly within and partly without it. Every part of the human body has a correct name, and it will be a useful first step if we get to know those names. The main external regions of both the back and the front of a human body are shown in figs. 1 & 2 (p. 8).

The popular names are printed on the left side of the page (the right side of the figure) and the scientific names which correspond on the other side.

In life all these parts are covered with an opaque skin through which we cannot see the inner regions. Can we learn anything at all from the outside? Yes—a good deal.

If we watch someone quietly sleeping we may get a

clue to one of the great facts of life. The active movements which the higher living organisms all show, and which distinguish them from inanimate objects such as stones, and even trees waving involuntarily in the breeze—all such movements cease in deep sleep; and yet if you watch beside the very quietest sleeper, you will see that there is constant movement—a gentle rising and falling of the chest that we know as breathing. While we live we breathe ceaselessly night and day, year in and year out. How and why we breathe is considered in the next chapter.

Return to consider your sleeper. If you are a swift observer you may notice, in addition to the breathing, that in the side of the neck and also on the surface of the wrist there is a faint throbbing. We can feel this throbbing better by pressing gently and firmly on the muscles at the front of the wrist as the doctor does when he "counts your pulse." This throb is that of the heart beat, which also goes on incessantly during the whole of our lives. Our very existence depends on two regular and rhythmic forms of movement. In addition, the very deepest sleeper generally shows some other slight muscular movements—the flickering of an eye-lid, the trembling of a lip, or the sleeper may move or turn his body, but these muscular movements are not regular, and they vary according to circumstances. The two great rhythmic movements of breathing and heart-beating, however, are, within small limits, steady and incessant. They are the basis of life. There are other internal movements which also are incessant, but these two may serve as a

starting point for our study of our own lives. These tell us that while "we ourselves" sleep there are within our bodies forces which work ceaselessly and harmoniously and without ever a "strike" or a riot. These forces are in actual fact the resultants of the activities of communities of cell-lives.

Yet the units of these hidden communities are each so very small, by what mechanical power can they lift the heavy sleeper's chest and draw air in and press it out? By what machinery-like arrangements can they pump so steadily through the firm tissues of the arm? To answer these questions we must know how all the organs and tissues fit together and co-operate, and for this purpose it is best to have a plan or model of all the various parts in their places. This is provided at the end of the book in an atlas which, though simplified, gives a fair idea of the shapes, sizes and relative positions of the larger and more important organs of the human body.

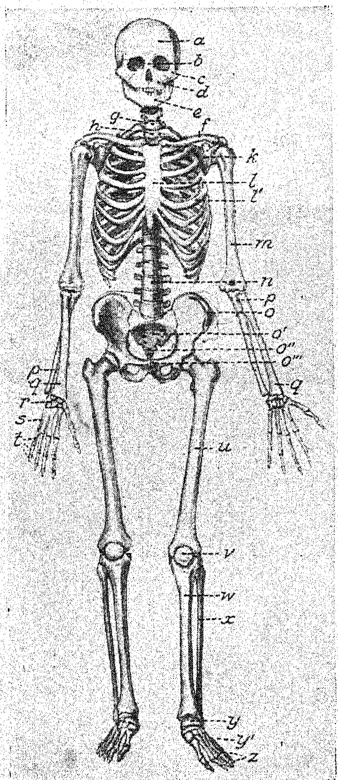
Study this model, unfold the parts, and try to feel in your own bodies what you can see there drawn in contrasting colours so as to make the relations of the parts clear like a diagram. When considering this general plan of the principal organs and structures inside the body, you must first realise that most of the masses of cells combining to do the work of the human functions are each individually soft and delicate. A human liver, for example, is much like the liver we can see in a butcher's shop, cut out of a cow or sheep, and it is quite squashy, a soft mass, the weight of which presses upon itself. By itself it would not have any active power to

retain its form in the stress of the outer workaday world. This applies to nearly all the organs. The upright form, the alert swiftness in action which characterises a healthy, properly trained human being, depends very largely on the internal scaffolding and main support which the bones give to the body. The bones in fact are an essential kernel of strength round which the muscles group themselves and to which they are attached in a variety of ways. They give the power of movement to the body and help to sling up and support, in the various necessary ways, the heavy soft organs which play their various parts in the body's manufacturing systems. Unless an accident takes place most of us never see our bones, but we can all feel round them, particularly easily at the elbows, the knees and the various knuckles of the fingers. The scaffolding formed by the bones is apparent in a complete skeleton. If its bones are wired together, it may be made to stand upright, when it has somewhat the shape and form of a man. This is seen in fig. 3 (p. 14). The names of the chief bones are printed below the accompanying diagram so that those who wish to know them can find them, but there is no need for everyone to learn them at this stage.

As most of you know the bones by themselves, although the important scaffolding of the body, do not hold together if the soft parts are removed. The separate bones are let into the body much as whalebones are let into a stiff belt, and they require the soft webbing of the outer material round them to hold them in place. Then they in turn support and stiffen the whole. Muscles

and tendons do this in ways which will be shown in various diagrams throughout this book. All the skeleton

**The Bones of the Skeleton, held together in their natural position.**




*a Frontal bone*
*b Nasal bone*
*c Zygomatic bone*
*d Maxilla*
*e Mandible*
*f Clavicle (collar bone)*
*g 7th cervicle vertebra*
*h 1st thoracic vertebra*
*k Scapula*
*l Sternum*
*l′ Rib*
*m (Arm) Humerus*
*n Lumbar vertebra*
*o Ilium*
*p Ulna*
*q Radius*
*o′ Sacrum*
*o″ Coccyx*
*o‴ Pubis*
*r (Wrist) carpal bones*
*s Metacarpal bones*
*t (Phalanges) Bones of fingers*
*u Femur (thigh)*
*v Patella*
*w Tibia*
*x Fibula*
*y Talus*
*y′ Metatarsal bones*
*z (Phalanges) Bones of toes*

FIG. 3.

bones, and the muscles and tendons, and the skin which holds the whole complex together and wraps it tightly, are all really subservient to the important manufacturing

and living organs of the body which do the vital work. These are arranged in the body cavity, and most of them are contained in what we call the trunk or abdomen. The plates I to VII in the atlas at the end of the book will show their arrangement more effectively than the longest description.

A curious and interesting feature about the structure of the human body which most people who write books about the subject either forget or ignore, is that the central, solid-appearing part, the main trunk of the body, is really a hollow cylinder. Though it is not round, being somewhat flat, and having an external bilateral symmetry, the trunk is a hollow cylinder round a long hole, and that hole is lined with special layers of cells which vary somewhat in different regions, but are continuous throughout. The body cavity itself is the portion which contains all the vital organs of the body, and this is completely closed in and shut away from the central hollow, which is open at both ends to the outer air, and runs from the mouth to the anus.

To make this clear, think for comparison of a muff with its skin or fur outer coat joined at each end to a silk lining; and the place in which you put your two hands at each end of the muff is a hole open to the outer air, although you call it the "inside" of the muff. The inner silk lining is joined on to the skin or outside, but all round the muff is the real inside into which your hands do not get, but which contains the wool or silk padding and a certain amount of space. The human body is like that: we have our outer skin, which can be compared

**The hollow canal, running from mouth to anus, through which the food passes without entering the body cavity.**

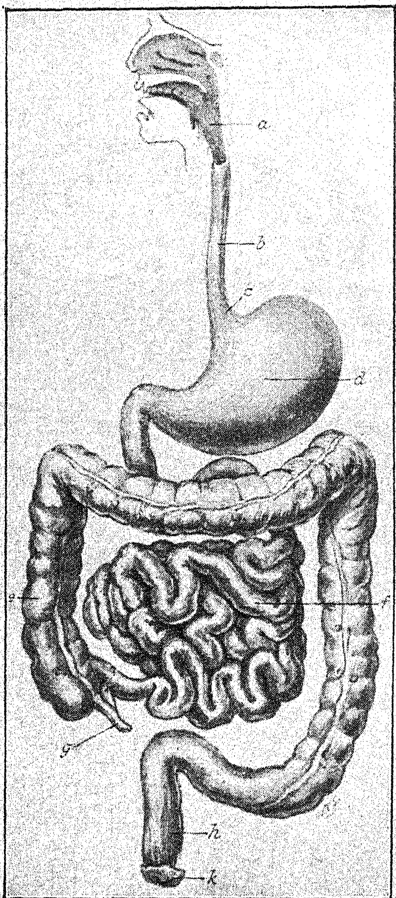



FIG. 4.

*Diagram of Alimentary Canal. For full description see figure 23, page 78.*

to the skin or fur of the muff, then at our lips we see the join where the thinner inner skin or lining meets it. You can see from the surface of the lip itself where that commences. The lips have a redder, brighter, thinner covering than the outside skin to which it joins, and the covering of the mouth corresponds with the silk lining of the muff, and continues right on down the throat, down into the stomach, right down through the long extensions beyond the stomach called the intestines or bowels, which twist on themselves, (see Plate II and fig. 4), right through them to the opening at the other end which is called the anus, which has also a very soft and delicate lining. The general appearance of the whole tube, from en-

trance to exit, is seen in fig. 4. There is, therefore, one central cavity open to the air at both ends and connected quite neatly and definitely on to the outer skin of the body. You have, that is to say, a hollow of complicated shape (because it has got twisted up, but was originally, and is fundamentally a straight tube) right through the centre of the body. It has its own definite lining, and at no place does the real inner cavity of your body come in contact with the open air any more than the inner cavity of the muff pokes out through the lining unless there is a tear. Round this hollow through the centre of your body is the space of the body cavity itself in which are packed the vital organs.

A side branch from this central hollow is specialised with very many small ramifications which form the lungs. Hence, all the traffic of molecules between the living body and the outer world, the interchange of oxygen and the wonderful merchandise involved in the food and drink which are absorbed, worked up and exchanged by the vital organs inside the body cavity proper, all depend on the behaviour of the very thin and absorbent lining in its various parts along the hollow which starts in your mouth and goes right down through your body. Along the main hollow down your throat and on to the stomach we find that the different regions are lined in special ways. The details of the absorbent lining vary in different zones, and also the bands of muscles contract and move in various ways, so that there is, for instance, the churning action of the stomach which helps to digest the food,

the squeezing motion of the intestines which pass it along and so on. Dissolved food is then absorbed in the lower portions of the body after it is more or less completely digested, *but the solid food itself in its raw state, and the open air never enter your body cavity,* although you put food in your mouth and swallow it down the hollow which we call the stomach, and which we think of as being inside the body, and though you breathe air in and out constantly. Food is merely temporarily kept inside the central hollow of the body, just as a hand temporarily inside the hollow of a muff touches only the inner lining but never touches the real inside.

Now bearing this great generalisation in mind, let us imagine that we are cutting through the outer skin and beginning to explore the structures and organs inside the body. As we cannot do this, let us look at the detailed plates at the end of the book which will give you some idea of what you would find if you were able to open yourself up. Under the skin lie muscles, like bands of semi-elastic material, over-lapping in many directions. Very strong bands of muscles hold the lower part of the body-wall firm, many series of overlapping strands support and give play to the arms, legs and throat. Some of those are seen in place in plate I (Atlas at end), others are cut away to show deeper lying muscles. In the upper part of the trunk beneath the muscles in front you will soon come to the side ribs. See plate II, 5. Together they form something like the bars of a cage. They are extensions of the processes of bone from the back of the spinal segments (see Plate VII) which come round to the

front and are there held together by a solid plate, the sternum (see Plate II, 6). The ribs protect some very precious and vital organs, chiefly the lungs, the heart, and the upper part of the stomach. You will find these organs arranged approximately as they are in life in plates III and IV. The cut ends of the ribs are seen in plate III, 4, the lungs at 2 and 3 in the same plate.

We have two lungs within the ribs placed nearly equally on either side, but only one heart, placed somewhat slantwise near the centre of the upper part of the trunk (see plate IV, 9). The lower part of the trunk is soft and without a bony cage and is called the abdomen. A large part of this lower portion of the trunk is taken up with the long and soft tube of the intestines, a continuation of the stomach, which winds backwards and forwards on itself, and in an ordinary grown man is about 28 feet long. The intestinal coils are seen in their natural position in plate II, 10, 11, 12 and 18, and pulled out to show the membrane holding them together in plate III, 7–13.

Behind this mass you will find two small and less conspicuous, but vitally useful organs, the kidneys, which have a very important part to play, see plate IV, figs. 13 and 22. The bladder and the lower part of the intestines, which gets much wider towards the end, and which is then called the large intestine, lie in the base of the main trunk, more or less protected by the big bones of the pelvis or hip (see plates II and IV). In girls and women the two ovaries, and the one central womb, lie in the lower half of the trunk (plate VI). In boys and men

these internal organs are quite atrophied, and the sex organs to correspond with these lie externally (see fig. 47). There is no need at this stage to consider the various organs and structures in detail; but with the labelled ground plans of the plates before you, you can find each organ in position as they are mentioned in the chapters which follow.

As you will understand, with whatever function, with whatever structure we begin our study, we must always break into a charmed circle of activity and we cannot understand completely any one thing that we are looking at or studying until we know something about them all. So the best plan will be to get a broad general idea of the arrangement of the body by studying the plates, and then to read the chapters one by one, after which I hope, by the time you reach the end of the book, you will have a clear general idea of the way a human body is constructed and performs its complicated work.

19/9/31

## CHAPTER III.

### *Movements of the Body : Breathing.*

WHEREVER we break into the charmed circle of the knowledge of our own bodies, we must feel that we want to know everything on either side of the point wherein we make our entry, but as that cannot be we must plunge in somewhere and work our way round the cycle. Let us begin with breathing because it is the easiest to observe of the regular movements of the body.

Lay your hand upon your own chest and breathe. If you press firmly, you will feel, beneath your chest-muscles, the bones of the ribs rising and falling as you take in and let out your breath. How these ribs are arranged you can see in the skeleton fig. 3 on page 14 and in the atlas plates II and VII at the end of the book, which you can open out so as to see how the soft lungs are encircled and protected by the cage-like ribs. Some of the ribs are fixed both back and front ; all are fixed at the back to the spinal, or back bone, and if you feel your own chest you will find the strong plate in front on to which they join and which is called the sternum, and which prevents you pushing your fingers very far into your chest. Directly you get to the bottom of that you can dig your fingers far further into the soft parts below. Then, on either side, you can feel what are called the

floating ribs which come down almost to the waist. These you will feel most readily moving in and out as you breathe and fill your lungs with air just as a pair of bellows fills up with air as you blow them.

Part of this bellows-like apparatus, which in a way corresponds to the piece of folded leather at the back of the bellows is the dividing partition called the diaphragm (plate IV, 25) which lies below the lungs and separates the body-cavity of the upper part of the chest from the lower abdominal body-cavity. This is a thick and very important membrane, and although the ordinary person does not know how to control its use, the value of the control of the diaphragm was known to the ancient Greeks, and those to-day who are wise will not only move it as all do, unconsciously when breathing, but will learn to move it at will with direct knowledge and control. Particularly as people get older, unless the diaphragm is kept under conscious control the muscles of the lower part of the body tend to sag.

The pumping apparatus of the lungs consists of the thorax, the diaphragm, the ribs, and all their various muscles. When the thorax is increased in size, air goes into the lungs. The muscles act so as to flatten the diaphragm and raise the ribs, which increases the size of the thorax, and air rushes into the lungs in an *inspiration.* Air is forced out in an *expiration* by the elastic retraction of the thorax in quiet breathing. This is aided by the action of the opposing muscles in more forcible breathing.

Under the ribs lie the paired lungs (2 and 3, plate III), each a large and lobed mass of spongy tissue, lying on

either side of the thorax. They are richly interspersed with the fine capillaries of the blood system, and the membranes formed by their tissues are thin and moist so that air can be absorbed through them. Their work is the exchange of gases between the body and the outer air. The gases (chiefly oxygen, nitrogen and carbon-di-oxide) pass directly through the very delicate membranes of the ultimate alveoli. These are small sacs, grouped as are bunches of grapes, into which the fine air-chambers lead. To keep the air constantly changing large quantities pass in and out through the main air channels. Their arrangement can be seen in diagrammatic form in fig. 5, where the large pipes and channels carrying the air into and from the spongy tissue of the lungs are most conspicuous. The top of the central wind-pipe (leading directly from the mouth) is enlarged somewhat in the form of a triangular box, with tough resilient sides. It is the voice organ (see *a*, fig. 5) and associated with it are strands of cartilage and

**Drawing of the throat with the air passages leading to the lungs.**

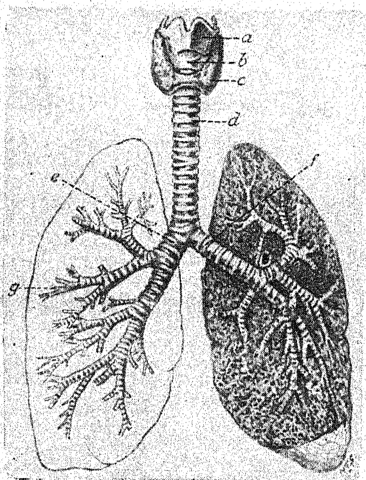



FIG. 5.

*a Larynx*
*b Cricoid Cartilage*
*c Thyroid Gland*
*d Trachea*
*e Right bronchus*
*f Left bronchus*
*g Bronchial tubes*

elastic ligaments, the *vocal cords*, whose movements control the speaking tones as the air passes and vibrates them.

Below the larynx the wind-pipe runs straight down as a wide tube called the trachea (*d*, fig. 5), but when it gets to about the level of just below the collar-bone, it branches into two big side pipes—each called a bronchus. When a cold or inflammation settles on these pipes, people suffer with what is called bronchitis, a very troublesome and sometimes dangerous disease which hinders the breathing. No human being can be comfortable without easy breathing nor can a man live without breathing the necessary amount of air in and out.

These two main pipes running to either side branch and divide into smaller pipes, as you will see in the diagram, and lead ultimately to the fine little sacs composed of very soft cell tissue of the lungs proper.

The cells of the membrane lining the air channels are like other inner lining or epitheleum cells, but they possess adjacent to the cavity minute projections or hair-like *cilia* which wave rhythmically so that any minute fragments of dust or germs which get into the air channels are brought back again into the throat and can be coughed up in mucus. These cilia are among those spontaneously moving cells mentioned in Chapter 6, page 66.

We breathe in, hold the air for an almost imperceptible pause, and then breathe out again, time after time, regularly all our lives from the hour of birth. A very easily performed experiment to show that the lungs do

take in air is that of squeezing out all the breath you can and contracting down your body as much as you can and then trying to hold your breath for as long a time as possible. Some people succeed in remaining without breathing longer than others, but even the strongest and most determined man will have to give in after two or three moments at the utmost, and then will feel the air rushing through his mouth and nostrils and into the lungs as he gasps for breath. Those who have studied chemistry or have had an opportunity to work at practical physiology can test the quality of the air which comes out of the lungs, and they will find that it is a little different (although not very greatly different) from the air which went in. Anyone can see the results of one difference by breathing out through a straw into a glass of clear lime water, which becomes cloudy as a result. The essential physiological process of breathing consists in the continual taking in of the fresh air around us, holding it briefly in our lungs, and then expelling air which is slightly different in quality from that we took in. The actions of the muscles and ribs are accessory, and assist in securing due entrance and exit of air particles. We breathe, therefore, to take air into the special sacs called the lungs. Remember that they are side branches of the lined hollow cavity and that the air does not get *direct* into the body cavity (see p. 17 *ante*).

The amount of air which can be held in the lungs is considerable and consists of not only the air which comes in and out readily, and diffuses from the upper to the inner and more remote portions, but also the deeper air

which is not so frequently exchanged and which remains much longer in the lungs and changes its nature slowly by the diffusion of gases, giving up the pure oxygen and accumulating carbon-di-oxide from the body cells.

**Teeth, Tongue and Tonsils.**

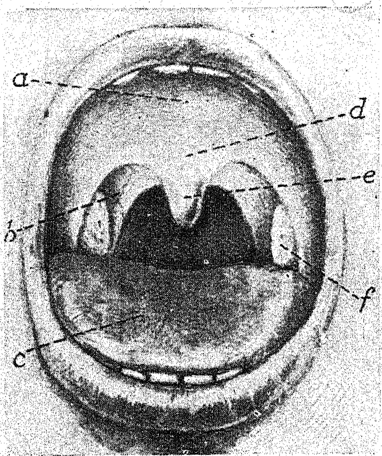



FIG. 6.

*a Hard palate*
*b Posterior pillar of the fauces*
*c Tongue*
*d Soft palate*
*e Uvula*
*f Tonsils*

A grown man's lungs contain about 200 cubic inches of more or less *stationary air*, and at each breath about 30 cubic inches of air are changed by being breathed in and out.

Let us now consider what happens to the air that enters. In fig. 6 you will see a wide open mouth showing the central track, the top of the wind-pipe or larynx, down which the air passes. In this diagram notice particularly the tonsils on either side. When the tonsils are inflamed and swollen, they too obstruct the breathing and are troublesome. The central air channel can be reached in two ways, direct through the mouth, and also through the nose.

Breath, that is to say air, can enter through the two nostrils, and those who breathe properly take the air in

through the nostrils, and pass it out through the mouth. The air coming in through the nostrils is warmed so as not to chill the lungs, and also cleared of some of the coarser dirt and dust particles by the hairs in the nostrils, so it enters the lungs *clean* and *warm*, which is what is required for perfect living action. The two nostrils unite higher up the nose with the channel which carries the air down the back of the throat into the wind-pipe. These two external channels uniting in the throat you will see in the diagram, fig. 7, p. 28. The tongue, although it moves about at will, tends, while breath is entering the body, to lie flat, so as not to block the entrance to the larynx at the back. Now this entrance to the larynx and wind pipe leading to the lungs is only a branch of the main cavity which runs right through the body, which I have already mentioned, is like the lining of a muff, and into this there enters both the air which goes specially into the lungs, and the food which goes down the central channel into the stomach and intestines. It is very important that food should not enter the special branch gangway off from the main channel, through which the air goes to the lungs, because food blocks and injures the lungs. Hence there is an ingenious automatic closure of the back of the throat partly by the arching of the tongue, partly by the epiglottis (see fig. 7) and the curtain of the uvula assisted by the muscles at the top of the wind pipe.

All the special apparatus, and the constant movements of breathing are designed to bring *air* into the system. What do we want from it ?

Air is invisible, except under special circumstances of radiation, as for example the quivering of very hot air

**Section through the front of the face, to show the air passages in the nose and mouth.**

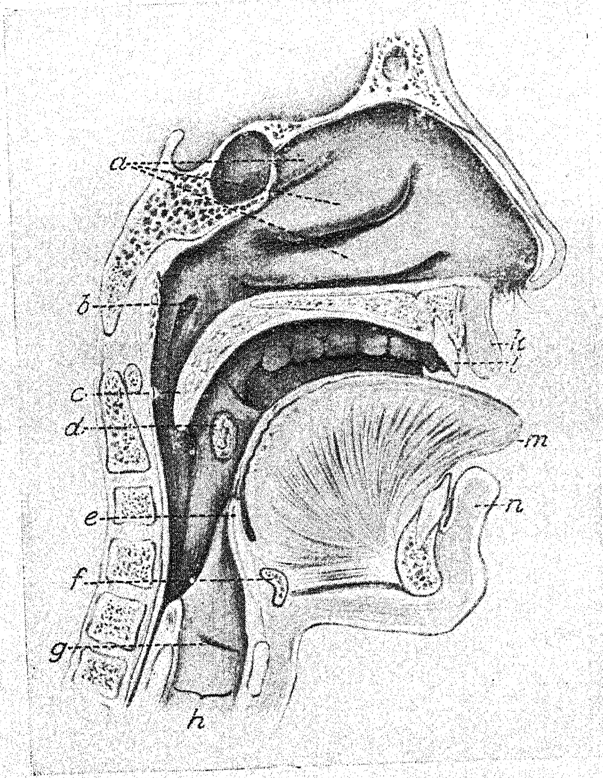



FIG. 7.
*For full description see figure 33, page 132.*

over a sandy shore in the sun, but from the study of chemistry it is known that it consists of a mixture of

gases, chiefly of oxygen and nitrogen—together with small quantities of other gases including traces of the very rare argon and others, and a small percentage of carbonic acid gas. This last ($CO_2$) is very important in connection with all life, both that of plants and animals, because all the carbon products of the world, including all starchy foods and even all the thick coal seams stored in the past epochs, and to-day all the carbon containing food which we and *all* animals eat, has been manufactured direct by plants from the carbon dioxide gas even though it is only a decimal point percentage of the total gas in the air. This will be referred to again (see Chapter VII.). For our own lives we require to absorb fresh oxygen, but as a side issue of our breathing we increase the amount of carbonic acid gas in the air, and, therefore, we increase the basis of food material available for all the plants, though we cannot use it ourselves.

The proportions of the air which we inhale are (leaving out the decimal points), in each 100 lbs.:

| | |
|---|---|
| Oxygen .. .. .. .. .. .. .. | 21 lbs. |
| Nitrogen .. .. .. .. .. .. | 79 lbs. |
| Carbonic acid gas .. .. .. .. .. | .04 |
| Other gases .. .. .. .. .. .. | A trace |

but when we test the air which comes out of the lungs, one 100 lbs. then contains

| | |
|---|---|
| Oxygen .. .. .. .. .. .. .. | 16 lbs. |
| Nitrogen .. .. .. .. .. .. .. | 79 lbs. |
| Carbonic acid gas .. .. .. .. .. | 3.99 lbs. |
| Other gases .. .. .. .. .. .. | A trace |

The Nitrogen remains so nearly the very same amount that by ordinary tests it seems the same. It is a neutral gas, apparently of little direct use to us or any other of the higher forms of life. In one way you may look upon Nitrogen as simply diluting the Oxygen which would be so strong as to intoxicate us otherwise. The important difference between the air breathed in and the air breathed out lies in the 4 lbs. of Carbonic Acid Gas coming out. How does this get into the air of the lungs and where does it come from ?

If we follow the fresh air taken into the nostrils down the wind-pipe, through the bronchia into the lungs, we find it reaches ultimately the surfaces of the lower air membranes of the lungs themselves. These are composed of thin soft cells, among which run a very large number of minute blood vessels called capillaries (see also Chapter IV). The oxygen in the air can pass through that fine living membrane, and it has an " affinity for " as chemists say, or is desired by, some of the components of certain cells in the blood, *i.e.*, the hæmoglobin in the red blood corpuscles passing in the blood stream through the finest blood vessels. By the hæmoglobin the oxygen is taken up out of the air mixture from the lungs into a kind of loose compound or solution. Here then is a curious and interesting truth, namely that, although we live in the air, we cannot use the atmospheric oxygen direct. Just as solid food does not enter our body cavities but is restricted to the lined hollow or channel of the digestive tract, so the crude air does not enter into the body cavity, nor go direct to the cells, but when it reaches the end of

the complicated passages of either lung, it has to pass into solution in soft living cells before it can enter the body cavity and reach the tissues which require and ultimately use it. The air particles pass through the soft living membrane by a process called "diffusion." This can take place in non-living membranes, such as sausage skins, and can therefore be studied by exact experiments.

You know that fish living in the water, either of sea or river, gasp and die in the open air. Fish "breathe" the water through their gills, taking from water that amount of oxygen, dissolved in it, which they require; and human breathing is much more like that of fishes than appears at first sight. Our bodies are arranged to suck a constant supply of fresh air into the specially contrived complicated sac-like cavities prepared for it. But the atmospheric air in the form of gas does not penetrate the body cavity itself. It has to enter in solution through the blood corpuscles, then to be carried in the blood stream to the tissues of the organs in the body cavity and the muscles where it is absorbed and used as required. At the same time blood corpuscles bring the waste products, also in solution, particularly including the carbonic acid gas which is exchanged for the oxygen on the return journey through the lungs, so that the carbonic acid gas comes out of solution from the inner tissues of the body and is carried back and once more exchanged into the air of the lungs and is then expelled through the mouth.

You may ask why it is carbonic acid gas which comes out in the air expired? Carbonic acid gas, $CO_2$ is a waste

product of "burning" organic matter, that is to say chemical molecules and compounds containing carbon split up so that one carbon atom "burns" or unites with two oxygen atoms so as to produce $CO_2$. You may ask where in our bodies is any burning taking place? The answer is, in every living tissue cell,—and all the time—though sometimes more and sometimes less. In all those groups of factory cells, such as the liver and the various organs all over the body, and particularly in the muscles with their ceaseless high pressure activity of movement, organic molecules within the cell structure are being burned. They burn so slowly that they make no fire nor flame, although it is their burning which gives us our body warmth. If it were not for the burning of portions of these cells constantly both day and night our bodies would be cold and all our vital processes would cease as they do in death.

The blood which contains the blood corpuscles freshly charged with oxygen from the lungs is bright red and is called *arterial blood* (see also page 37), while the blood which comes back on the return journey, after having travelled round the body has given up its oxygen, and received carbon di-oxide and other waste products, and is darker and purplish instead of scarlet in colour, though not "blue" as so many people imagine. This blood is called the "*venous*" *blood* because it travels back in the veins into the heart to be pumped round afresh to the lungs to get charged once more with fresh oxygen, when it will become "arterial" blood once more. You will already see that it is impossible fully to consider even

the one function of breathing without at the same time taking into account the circulation of the blood, and many other complicated mechanisms involved.

Such " burning " or breathing, whichever you like to call it, is a feature of *all* living cells, and is true of plant cells both day and night. But in plants the breathing is hidden by the active starch manufacture which *takes in* $CO_2$ from the air and leads to a confusion in some people's minds as it only takes place when it is light. It is when it is light not breathing but eating—a quite different process. Quietly and all the time plant cells, like animal cells, require oxygen to *breathe.*

Regular breathing varies a good deal in individuals, and also varies according to the amount of exercise taken, the temperature of the room, and so on. That is to say, breathing varies somewhat with the external environment. It is also faster and the breath intervals shorter in a child than in a grown man, but roughly speaking adults breathe 18 or 20 times per minute, within certain small limits it can be controlled by the will, but not completely.

A boy who is running a race or anyone who has been playing an active game such as tennis, pants, and may even gasp for breath. This is because the muscles are using up their vitality and burning away more quickly than usual, to supply energy rapidly for the active muscles for which the usual rate of breathing does not supply oxygen fast enough. On the other hand when one is sitting in a very hot room with windows closed and thick clothes covering the whole body, there is a sluggish lack

of vitality in the tissues and one breathes lightly and superficially until the stuffiness of the room makes one gasp for breath or get out and freshen it. This leads to an interesting point: The general impression is that a closed room needs freshening because the oxygen is all "used up," but that is not really so. The room feels close chiefly because of the increased percentage of water vapour in the air, and particularly because of very minute poisonous organic substances which come off in that water vapour and tend to permeate the air with subtle poison. Water vapour from the lungs, although invisible in a warm room, is always coming out with the breath, and as it accumulates the amount of moisture in the air becomes uncomfortable, and also contains an increasing percentage of those very subtle organic poisons, the true nature of which science does not yet know, but the unpleasant re-actions of which every sensitive person feels in a stuffy, crowded room.

## CHAPTER IV.

*Movements of the Body: The Beating Heart.*

LONG before birth, ceaselessly, to the moment of death, the human heart beats within the body, and the effect of its beating is felt all over the body. A careful observer watching a sleeper may just see the delicate throbbing in the neck, but it is better observed by pressing firmly on the wrist when the beats can be distinctly felt and counted. The regular beat varies with the activities and age of the owner of the heart, but for grown-up people it is generally something between 70 and 80 each minute. It beats much more quickly after running, playing tennis, or such active exercise, and it beats more slowly before rising after a long period of rest and sleep, but even when beating slowly the heart has no holiday, and on its ceaseless work depends the life and health of the whole body.

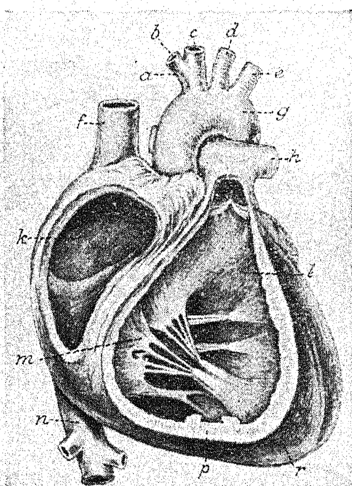
The circulation of the blood was discovered by William Harvey, an Englishman, born in Folkestone in the year 1578, although, of course, long before that, men realised that the heart and the blood were of supreme importance to the body.

Most people know the general shape and appearance of the heart. No organ is more popular with artists and poets, and hearts are seen, crudely represented on sacred pictures and valentines till the heart has become sym-

bolised to imply much more than its natural functions suggest.

The heart is not a reservoir of blood but a pump, and by its regular pumping action keeps the blood which fills the whole system of the arteries, capillaries and veins circulating round and round the body. A sheep's heart,

**A heart cut open to show some of the great veins and arteries and the two cavities on one side with the valves.**




*a* *Innominate artery*
*b* *Subclavian artery*
*c* *Common carotid artery*
*d* *Common carotid artery*
*e* *Subclavian artery*
*f* *Superior vena cava*
*g* *Aorta*
*h* *Pulmonary artery*
*k* *Right auricle*
*l* *Right ventricle*
*m* *Valves*
*n* *Inferior vena cava*
*p* *Cut edge of muscle of heart*
*r* *Outside of heart*

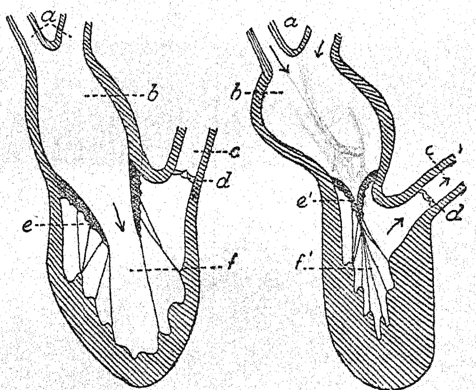
FIG. 8.

is, in many ways very similar to that of a man, and as it can readily be obtained from a butcher's shop it should be studied by those who desire to understand the heart's structure.

The heart is divided into separate chambers called the Auricles and the Ventricles in the manner indicated in

the fig. 8, p. 36. As the heart beats the blood pours through the valves from the upper chamber to the lower and then out through the great arteries which throb and expand under pressure as the waves of blood push through them (see fig. 9). The arteries all over the body have definitely elastic walls which expand with each onrush of blood, and it is the pushing of the blood through

**Diagram to show the way the valves of the heart work when pressing the blood forwards.**




*a* *Veins*
*b* *Auricle*
*c* *Aorta*
*d* *Semilunar valve*
*e* *Mitral valve open*
*e'* *Mitral valve closed*
*f* *Ventricle dilated*
*f'* *Ventricle contracting*

FIG. 9.

the expanding arteries which we feel at the pulse and elsewhere. The arteries branch and divide and run into finer and ever finer channels through the many muscles and tissues all over the body. A much simplified idea of their course can be obtained from studying figure 10, p. 39. In this diagram the main directions of the flow of blood through the arteries and veins are indicated by arrows. The main arteries and the great vein from the

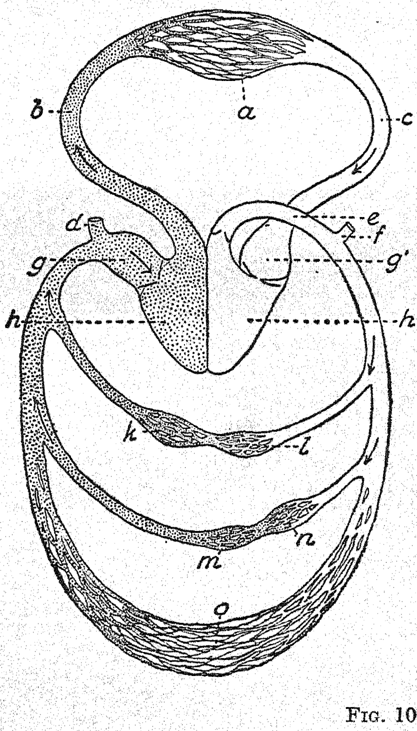
lungs which contains aerated or oxygenated blood are indicated by white canals, and the main veins and the great artery to the lungs which contain de-oxygenated or used blood, are dotted. The transition from one to the other takes place in the fine capillaries all over the body, and this very complex network is merely indicated by the mesh-work uniting the main trunks in the diagram.

A more accurate idea of the heart and some of the main blood vessels is to be seen in the atlas, plates IV & V. In this the arteries are coloured red and the veins blue.

If one follows the course of the blood from the heart, one sees that after much subdivision the channels of the arteries get so small that they finally merge into minute tubes with much thinner walls. These are called the capillaries, and run in fine mesh-works all over the organs, in the muscle tissues, and under the skin of the body. Here no definite pulse is felt because the rate of the blood-stream is much slower, although it is still definitely moving. The blood through the arteries is pressed forward by the pump-like action of the heart, but the force of this is lost in the fine capillaries where the rate of the blood stream slows down, just as the cataract of a mountain torrent slows down when the stream widens out into a large flat lake. The rate of the flow in the arteries, for instance, is as rapid as 15 inches in a second, but in the finest capillaries it is only one-twentieth of one inch per second, so that the pressure of the arterial push being lost, other means of assisting the blood to rise from the extremities of the body through the veins back to the heart are needed. This assistance is found in the valves

of the veins—little cup-like pockets attached to the walls of each vein all along its length, which, in the legs for instance prevent the blood flowing backwards instead of

**A Diagram (very much simplified) to show the general course of the blood circulation.**




The lungs?

*a* *Pulmonary capillaries*
*b* *Pulmonary artery*
*c* *Pulmonary vein*
*d* *Veins from head*
*e* *Aorta*
*f* *Arteries to head*
*g* *Right auricle of heart*
*g′* *Left auricle of heart*
*h* *Right ventricle of heart*
*h′* *Left ventricle of heart*
*k* *Portal circulation*
*l* *Gastric and intestinal vessels*
*m* *2nd renal circulation*
*n* *1st renal circulation*
*o* *Systemic capillaries*

FIG. 10.

following its course upwards. How, even with this assistance, it tends to accumulate you can easily see by holding one hand very still downwards, and another with the arm extended upwards. In a very few minutes the

The forearm and hand dissected out to show the arteries.

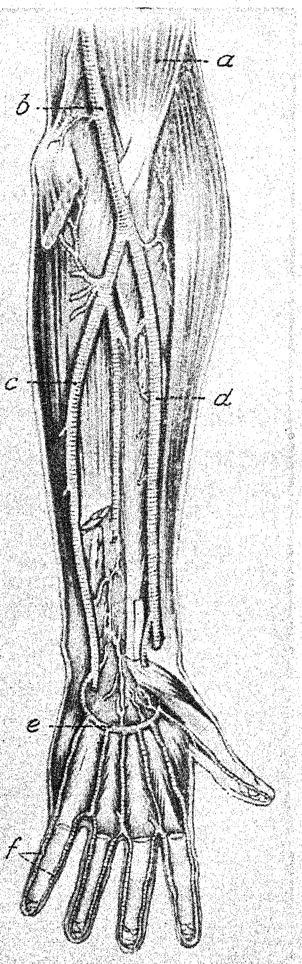



FIG. 11.

veins in the hand that is being held downwards will be very different from the other, and will be definitely swollen and congested. As a rule, however, we do not keep our limbs quite still, and our muscular movements assist the blood to travel along the veins and return to the heart.

The complexity of the system of arteries and veins is very great, and for an advanced study of the body it is necessary to know the names of all the numerous branches going to the different organs. For our purpose at present, however, that is not necessary. To give some idea of the complexity of the whole system, the scientific names of just one set of arteries, those in the fore-arm, are shown in a careful drawing,

*a* *Great muscle or biceps*
*b* *Brachial artery*
*c* *Ulnar artery*
*d* *Radial artery*
*e* *Palmar arch artery (note the loop of the artery across the hand)*
*f* *Arteries to fingers*

**The intestines mostly cut away (parts left see *k* and *p*) to show the main veins and arteries supplying the kidneys and ovaries in a woman.**

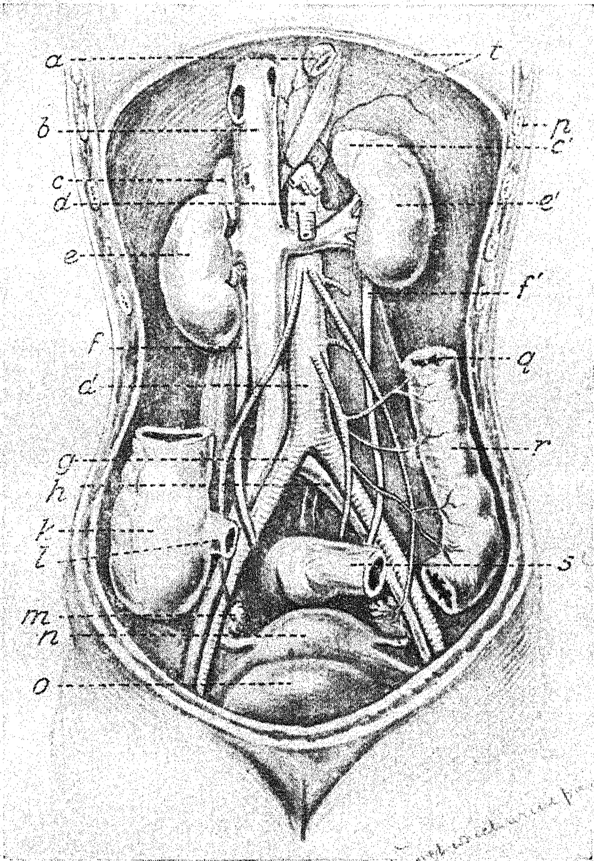



FIG. 12.

*a* *Œesophagus*
*b* *Vena cava*
*c* *Right supra renal gland*
*c'* *Left supra renal gland*
*d* *Aorta*
*e* *Right kidney*
*e'* *Left kidney a little higher than the right*

*f* *Right ureter*
*f'* *Left ureter*
*g* *Common iliac artery*
*h* *Common iliac vein*
*k* *Cecum*
*l* *Ileum*
*m* *Ovary covered by processes of fallopian tube*

*n* *Uterus*
*o* *Bladder*
*p* *Cut end of rib*
*q* *Cut end of descending colon*
*r* *Descending colon*
*s* *Rectum*
*t* *Diaphragm*

22



fig. 11, p. 40. Here the details of a fore-arm are dissected out so as to show the course of the arteries, and how they lie and branch among the muscles. This system is merely one example from the great complexity of blood vessels all over the body and limbs.

Some of the important arteries in the body cavity should also be known to everyone and in fig. 12, p. 41, you will also see some of the main arteries supplying a variety of different organs, with the principal veins for the return flow of blood with them. These are seen coloured red and blue in plate IV. There the great central artery and the corresponding vein lying side by side are conspicuous—thick canals each of which branches in many directions. In fig. 12, for instance, notice the renal artery on one side going to the kidneys, and the renal vein coming from the kidneys on the other side. A series of branch arteries go to the intestines, and particularly you can see those to the colon, which is partly cut away in this diagram. High up along the main artery are two long fine arteries one on either side running down to the ovaries, those important structures which give rise to the egg cells, each of which has a special artery of its own.

Without going into further detail enough has been said for you to realise that just as in a well-built house there are complicated systems of drains, water-pipes and gas-pipes, so in the human body there is this very complicated service of blood vessels leading to and from all the tissue systems in the body. It is now time to consider the contents of these channels.

*The Blood.*

Blood is a fluid, well-known to us by appearance for its bright crimson colour, and by repute for its vital importance. Whenever we gash or prick ourselves blood flows; if we cut deeply into an artery it spurts out in a bright red stream; if we cut or scratch a vein it comes rather more slowly and is slightly darker and more purplish in colour.

If a drop of the fluid is placed on a glass slide and examined under a microscope, we find it is not a simple liquid such as a drop of wine would be, but that it consists of a transparent fluid of yellowish colour (called serum) in which lie a large number of small roundish objects, separate each from the other, each of which is an independent cell. These are the so-called corpuscles of the blood. These corpuscles are of two kinds, the red corpuscles and the white corpuscles. The red corpuscles are those which give the colour to the blood, and which are of prime importance in carrying oxygen from the lungs to the tissue cells all over the body. They contain a substance called hæmoglobin, which has the very special property of taking oxygen into partial solution or combination and yielding it up readily when placed in touch with other cells which are hungry for it. This hæmoglobin is a parallel in chemical structure to the active substance in plants, the chlorophyll.

The fine capillaries, in close touch through their thin walls with the living tissues of the body bring these blood corpuscles and the material in solution in the serum of

the blood into touch with the living cells. Through the capillaries the important exchange of oxygen and carbonic di-oxide takes place in the red corpuscles, and the quality of the blood therefore slowly changes from being what is generally (although not quite correctly) called arterial blood (that is blood with fresh oxygen in it or oxygenated blood) to venous blood, the blood of the veins. The fine mesh of the smallest arteries merges into the capillaries and in turn they join on to the small veins, which gradually unite and unite to make larger and longer veins in which the blood, altered in its composition by the exchanges which have gone on, travels up slowly and somewhat sluggishly back towards the heart.

If we were now to picture the blood system of the body in another way, we may look upon the red corpuscles as the merchants of a great country, in which there are a large number of busy factory centres, each with industrious employees working in one kind of material or another, but all requiring to burn oxygen and willing to give their own manufactured substances in exchange for this vital necessity for themselves. The oxygen-carrying corpuscles hurrying to and fro along the main lines of communication bring them oxygen on behalf of the whole community and take from them their excess waste carbonic acid gas. In return the cells work all the harder and the red corpuscles hurrying on with their load of waste material are carried round to the lungs once more where they exchange it with the outer air. The individual carrier-corpuscles can play their part in this process for a considerable time, but after a period the

red corpuscles become old and useless and wear out, and then they are cleared away from the blood by the spleen, an organ which you will find in its place in the atlas, plate IV., No. 11, and their place is taken by young and strong red corpuscles. When there is not a due supply of strong young corpuscles, the human being suffers from a disease called Anæmia, and this causes general weakness because all the tissues are stinted of the full supply of oxygen they need. Iron has a peculiar power, even in very small quantities, of stirring up the production of red blood corpuscles, and this is very interesting because plants deprived of iron have a similar disease and go pale till iron makes their green corpuscles active as they should be.

Food is just as necessary as oxygen to every cell in the body but food particles are not carried by the blood corpuscles, and they do not require special vital carriers of any sort. No solid food is carried round, and the food in solution is slowly absorbed into the blood and lymph streams in liquid form oozing through the cell walls by a process called osmosis. In the spaces between and around the organs and tissue cells the food solution merges with the lymph which lies all round the tissues and fills the spaces between them, and the exchange of nourishing molecules and waste products partly takes place.

The white corpuscles have a special job or rather many special jobs of their own, and they are perhaps best compared with the scavengers and the police of a human city. The white corpuscles have a particular liking for any trespassing bacteria and set upon them and destroy

them, eating them up. They also destroy and neutralise some of the waste products and poisons which get into the blood stream. If, for instance, a small poisoned thorn should penetrate into the tissues, numbers of white corpuscles will collect from the blood stream, and, working all together will endeavour to push it out, which they will eventually do with a little mass of pus which collects round the thorn.

Therefore, the blood, pumped so actively and continuously round the body has three main pieces of work to do for the whole body-community : to carry round the oxygen-containing cells ; to form a channel for the dissolved nutriment and food ; and to form a highway for the traffic of the special constable white corpuscles. Other and more subtle messengers undoubtedly travel to and fro in the blood stream, as well as in other ways in the body, and the blood itself has a variety of other qualities and duties, less obvious. For instance, the power of the blood to coagulate when it meets the air (as it does on the surface of a small cut) makes it a very useful healer and saves loss and injury to the whole body.

It is of particular interest to notice that every living tissue cell in the body still individually lives in a condition parallel to that of the primitive cell organisms of ancient life in far away days before the evolution of the higher animals had begun. That is to say each cell of the simple ancestral organisms used to live as a soft-walled protoplasmic mass, nourished by particles or solutions and by the fluid sea water, protected from the open air, and buoyed up by the sea water in which it

lived. Still to-day in our own bodies, owing to the blood and lymph fluids which permeate the whole body nearly all the living tissue cells of whatever type are working in a liquid substance (either blood or lymph) which buoys them up, nourishes them, and provides them with oxygen to breathe just as sea water did the ancient cells. So that though "we ourselves" live as human beings in the outer air, the only cells of our body which really live in the outer air are our skins—the outer skin of our face and hands and the inner linings of our lungs and throat, the rest of our cells all continue to live in a liquid environment as their ancestors did. The main body cells themselves never come into contact with the outer air at all, but they live as their primeval, free-living ancestors lived in a surrounding protecting, nourishing and oxygen-containing fluid. It is also curious to notice that just as that surrounding fluid for the primeval cells was sea-water, so to-day a normal solution of salt water mixes without danger with the blood, and is readily absorbed through living tissue into the blood stream, as we see when a normal salt injection is made.

Our body-community has organised itself in marvellous ways, and its combined powers are immeasurably different from the life of the original primitive cells, and this is all the more wonderful when we remember that the single cells of which our complicated tissues are built up still go on living in the truly primitive way, surrounded and protected by a fluid.

## CHAPTER V.

*Bodily Movements—Muscles.*

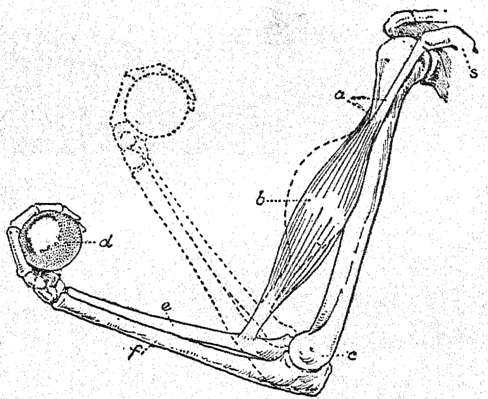
SOME or other of our muscles are moving almost incessantly. If you watch anyone who is sitting what we call "still," you will see the flickering of the eye-lids, the nostrils going in and out, a slight tapping of the toe, an occasional movement of the hand, a shifting of the position, in addition to the muscular movements involved in breathing and heart-beating. As you know from experience very few people really sit still for any length of time, so our usual movements are more active than these. Whether we are walking, running, playing, turning the pages of our books or whatever it may be, we are giving rise to constant muscular movements in our limbs and trunk.

The way that movement is achieved is, like everything else in bodily organisation a very complicated interlocking of a number of activities, and depends on the harmonious action of innumerable cells and tissues.

We saw in the general plan of the body (p. 41) that the trunk or main portion contains most of the various soft organs. They have to be carried about, and many things in the outer world brought into relation with them, and this is the work of the limbs. The limbs are specially adapted for movement and contain no vital organs, but are tense with muscles and all the accessories

muscles need, such as bones from which to get their tension and pull, blood vessels and nerves, and a skin over all. The muscles are all prepared for *movement*, and are attached in ways which give a great deal of free play to the limbs. The arms and legs, particularly the upper parts of the legs, the thighs, contain very large and powerful muscles, so attached to and surrounding the

**The bones of the arm attached to the shoulder to show how the biceps (muscle) works in movement.**




*a Tendons by which the biceps is attached to the scapula*
*b The biceps (power)*
*c End of humerus (fulcrum)*
*d Weight*
*e Radius*
*f Ulna*
*s Scapula, or shoulder to which the tendon ends of the biceps, (a), are attached*

FIG. 13.

bones, that they are finely adjusted for the movements which carry the body about. They perform the various pieces of work required to bring to the immovable central organs the substances needed from the outer world, and change the position of the trunk in accordance with the environment sought. They do all the manifold pieces of transport service which are required by a body in our civilised life.

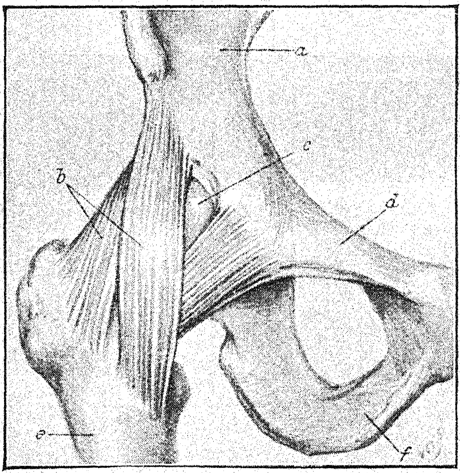
The muscles therefore in the legs and arms are specially organised to contract and relax freely according to the instructions they receive from headquarters, and the whole of our movements depend on the leverage which they can exert during this contraction and expansion. They get their leverage from their attachment to the central hard bony structures of the skeleton. The muscles indeed may be compared with strands of elastic, and any of you who have played with an elastic toy know that you cannot get any force in the pull unless there is something solid to which it is attached and from which it will rebound. So with the muscles.

The muscles of the fore-arm, for instance, which can contract and swell up, as you see when you bend the arm and feel the biceps rising, would be powerless if it were not that they play up against the solid arm bones. In simple diagrammatic form you can see the mechanism of this in fig. 13, p. 49. Each main muscle is a spindle-shaped mass of tissue cells, thick in the middle and tapering off to the tendon tissue at each end. The tendons are attached to the bones. The connective tissue which holds the loose bones of the skeleton together and the tendons of the muscles which are attached, sometimes sheathing and overlapping, not only play their part in holding the skeleton bones in their position, but make possible all the turning, twisting and bending movements which are so essential to our lives.

There are an immense number of muscles in the limbs alone, some of them packed together in very thick masses. For instance, the juicy beefsteak we eat is entirely com-

posed of the thick part of the muscle of the bullock's upper leg. Similarly we have masses of muscles in our own thighs. If you study the muscles in the leg of any of the animals we eat, even after they are cooked, you can see a good deal of the sheathing and overlapping of these muscle strands. They can be seen even better in

**The hip joint, showing the way the sheathing bands of muscles hold the loose bones in place.**




*a Ilium—part of hip bone*
*b The femoral ligaments attaching leg bone to pelvis*
*c Rounded end or 'head' of leg bone*
*d Pubis—part of hip bone*
*e Femur or leg bone*
*f Ischium—part of hip bone*

FIG. 14. *The Right Hip Joint*

the leg of an uncooked chicken or rabbit. It is worth while examining such an animal and everyone has the opportunity of doing so in the kitchen.

Now these muscles, like the rest of our bodies, are composed of masses of minute, almost or entirely invisible cells. Muscle cells are each rather long and spindle-

shaped, and they lie overlapped in strands between which is a kind of jelly which bathes and surrounds them. On the contraction of the single cells the contraction of the whole muscle mass depends. In the muscle masses are also the innumerable fine blood vessels and minute capillaries which carry the blood through the muscle tissue as through the rest of the body.

**The hip joint, with the muscles cleared away and part of the pelvis bones cut across to show the relation of the ball and socket of the hip and leg bone.**

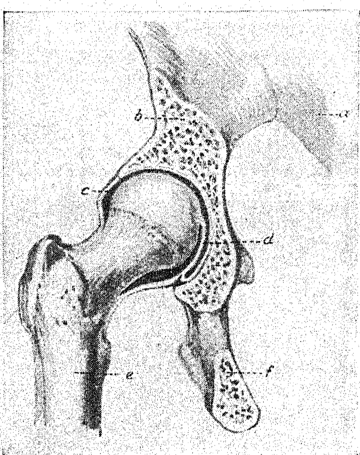



FIG. 15.

*a Sacrum*
*b Ilium (cut)*
*c Cup and ball cavity of hip joint.*
*d Round ligament*
*e Shaft of Femur*
*f Ischium (cut)*

An example of the way the muscle strands are sheathed round the bones and are attached to them is seen in the drawing of some of the muscles of the hip joint, fig. 14, p. 51. This should be compared with the other diagram of the hip bone (fig. 15) in which you see the central round end of the leg bone in its place in the socket and with the muscles cut away. Although the bone fits into the socket, it would fall out if it were not held there by the attached tendons at the ends of the muscles.

The way our bodies are held upright, and are able to bend and move in response to our own wills depends

almost entirely on the continuous contraction or expansion of many muscles. These muscles act without our conscious direction once we have learned to stand and walk; but anyone who has seen a baby clinging on to a chair for support, not able to stand without it, must realise that the simple act of standing upright (which has become to all of us so easy that our brains no longer think of it at all) requires to be learnt. The muscles which control standing have to learn how to adjust themselves to each other's movements and to hold the whole body upright by continually making slight movements themselves to counteract the natural tendency that the body has to collapse and fall down. Although our brains are not *conscious* of doing this, it certainly depends on ceaseless watchfulness on the part of some centre in our brains, because a man who has had his brain stunned by a blow collapses and falls down, although no muscle in his body is injured in any way.

Similarly the very complicated and difficult art of walking depends on the adjustment of the muscles. At first this is controlled by a conscious and deliberate effort of the brain, but grown-up people constantly engineer a more or less unconscious adjustment unless anything goes wrong and upsets the well-regulated balance.

In fig. 16, p. 54, may be seen some of the muscles of the ankle and foot dissected out so as to show the way they sheath and overlap round the ankle. This gives it its turning power and makes the subtle play of the foot and instep possible. On this our balance and power of walking and running depend. In this diagram also you will

see some of the arteries which run through between the muscles carrying the nourishing blood to the tissues.

**The foot dissected to show some arteries and muscles.**

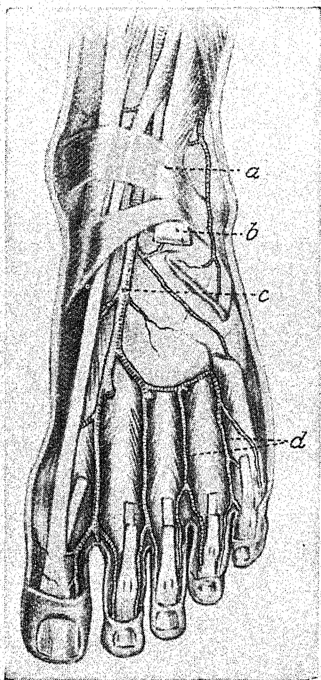



FIG. 16.

*a Swathing ligament of instep*
*b Cut end of muscle*
*c Dorsalis pedis artery*
*d Arteries supplying the toes (dorsal metatarsal arteries)*

All the many hundreds of muscles in our bodies have names, and those who specialise in a knowledge of the human frame have to learn them, but for our purpose the general structure of muscles is all that is required.

There are in the trunk muscles similar to those in the limbs, each primarily there to make various movements possible, but in addition their presence actually creates a sort of casing externally to the vital organs within and gives strength and solidity to the trunk. These are seen in Pl. I. of the atlas at the end of the book.

The sheathing outer muscles of the body wall or trunk, which resemble in their overlapping arrangement the muscles of the limbs, make a firm casing round the precious inner organs. In addition to their chief work of movement, they help to hold the body in proper shape and

prevent the organs within sagging out of place. Young people who play and run freely generally have firm enough abdominal muscles, but older men and women who neglect exercise and over-eat, get flabby and often allow these muscles to sag, and the whole body gets fat and out of shape. Then the inner organs drop out of place giving rise to various difficulties and diseases, sometimes to great pain. Most people are unaware that these muscles of the body-wall can be controlled at will and made to move just as freely and determinedly as the arms and legs can be moved. With a little experience the muscles of the body-wall will contract and tighten up as one wishes and this is not only an amusing and pleasing exercise, but is a great source of health and beauty when the first flush of early youth passes.

There are also different types of muscles equally, and even more important. Some of these are the muscles which hold the organs in place, and others are muscles which help the organs to move and do their specialised work. The heart, for instance, whose pump-like action we considered in the last chapter is composed of muscles of a very special kind—muscles which rhythmically contract with a strong pull, each contracting on itself and not attached to any bone or other fixed organ. Then there is the very powerful muscle of the diaphragm—a strong concave muscle going right across the central region of the trunk like a roof and floor partition dividing it into two main chambers.

Most muscles are like bands, straps, lenses or wedges of tissue, but there are a few which are semi- or completely

circular and those have a definite expanding and contracting to do like that of a diaphragm lens or a circular elastic band. Two important muscles of this kind are those round the mouth, which we can purse up or open out, and also the circular muscle round the anus, the opening at the other end of the alimentary canal, which closes in tightly or opens out as necessity arises.

*The cells composing the muscles* are of different types, the *voluntary*, those muscles whose contractions we can control and the *involuntary* or the uncontrollable muscles which go about their work without our knowledge. They are slightly different in their structure, although all consist of cells with protoplasm and living nucleus. The one type is "striated muscle" and this is due to the striæ or horizontal marking visible under the microscope in the protoplasm of each muscle cell. All our leg, arm, and general body muscles are striated in this way. Those of the internal organs such as the alimentary canal, the bladder etc. are made of cells with plain protoplasm.

The muscles that respond to our will, such as those in the arms and legs and others I have mentioned, do so as a result of an order to act which reaches them from our conscious thought. That thought is translated and conveyed to them in the form of a stimulus or shock, carried to them through the nerve cells running from the brain or through connections in the spinal column.

We know from the experiments of those who study animal structure that muscle contracts when stimulated by a swift shock. This can be seen when one separates out strands of leg muscle from an animal recently killed,

such as a frog, and then an electric shock, or even the touch of a sharp needle, will set the muscle contracting and thus draw the leg up as though the creature were jumping.

To bring into harmony the many muscles required to do a complicated act is very difficult—nevertheless, as we all know from experience, we may easily throw a stone to hit a wall, or even a small spot on that wall, time after time with perfect accuracy. In order to do this the muscles in the back and the body wall, and the muscles in the arms and legs must all contract in individual and different ways, and yet all we ourselves are conscious of is the intention that the stone has to reach a certain spot on the wall. How we do it, and the exact message our nerves convey to each of the many muscles of the arms, legs and back we have no idea, and all the study in the world will not enable us to know exactly what goes on in that wonderfully controlled mechanism the conscious brain and all the nerve cells in the body. But learned men who have repeated many experiments have proved that the contractions of the limbs which make it possible for us to throw that stone depend on some stimulus conveyed by the nerve cells to each of the local muscles.

Only muscles which have not been tired out by too frequently repeating the same piece of work, and only muscles properly nourished with a sufficient supply of food and oxygen will react and contract properly. It has been discovered that while working, the muscle cells give out waste products into the lymph which surrounds and bathes them, and if these waste products accumulate

too much and do not get carried away quickly enough then the muscle becomes temporarily poisoned and unable to respond when called upon. This is what happens when we get over-tired, either by repeating too frequently and for too long a time together the same movement, or when we over-tire ourselves generally by working too many hours on heavy work. The bat and ball or the weight we lift, which, at first, is quite easy for us to handle, gradually feels as though it were heavier and heavier, and then the limbs, instead of responding swiftly and lightly begin to tremble and quiver, and are unable to do their work neatly and with proper adjustment, and finally refuse to work altogether. Then the boy or man staggers forward and falls "dead tired."

What happens then after a proper period of rest and nourishment? The lymph and the blood stream carry away the poison accumulated and bring fresh nourishment to the starved cells of the muscles, and these after getting fresh food and a general cleaning up are ready to work again. Sometimes a very brief rest will restore the balance of the cells, because the hurrying blood stream and the ubiquitous lymph are acting and cleansing all the time, but if the system gets repeatedly over-tired and under-nourished, then the strength of the muscles suffers serious damage, and then no matter how peremptory the command from the brain, no matter how eagerly the person may desire to make any definite movement, the response from the muscles will not come, and the arm will sag or the limbs refuse to move, not because the

muscle cells are not there, but because they are not properly equipped to respond.

Hence you see, the voluntary movements of the muscles, which vary from day to day, depend on the linked up activities of many different cells and tissues in the body and all are ultimately dependent on the first fundamentals of food and oxygen.

# CHAPTER VI.

## *Movements : Of the Cells.*

ALL the movements considered in the last three chapters have been concerted movements of masses of cells, such as the movements in unison of the many cells in the heart during its beating or the simultaneous contraction of the thousands of cells in each muscle as it responds to a stimulus.

The movements of the *individual cells as separate units* raise many points of interest, for, as should by now be thoroughly understood almost the whole of our body with its muscular tissue and all the various internal organs each consist of immense numbers of cells massed closely together, so that any one cell has other cells, generally like to itself, all round it.

The movement of the individual cell, as distinct from the movements of masses of cells all together is, as a rule, only possible internally and within the limit of the cell itself. Such movement takes place in almost every living cell, and to understand the nature of this movement, we must first consider the structure of single cells.

That living tissue is composed of cells was first recognised in plants, and this was probably due to the fact that in plants the cell-walls which mark the cells off from each other are much stronger and more definite than in animals' tissue.

The first ideas about tissue cells therefore created the impression that they are to be compared with honeycomb, and resemble it in consisting of many similar hexagons closely interlocked and packed with some liquid content. This while true of a large proportion of living cells in the vegetable world lays too much stress on the cell-wall to be quite in true perspective when we are considering animal and human tissue. The majority of cells composing either the soft organs or the muscles of a human being are more irregular in outline, having much softer and less clearly marked walls than we find in plants. Yet if we concentrate on the essentials we find a profound similarity in the cells of all living tissues.

All living cells each consist of a mass of protoplasm which contains, generally toward its centre a more concentrated and richly granular protoplasmic part called the nucleus, something which one may compare with the kernel of a fruit, yet which controls the vital processes. More will be said about this later on pages 102-3.

Protoplasm is the basis of life and is a nearly colourless jelly-like substance. When examined without much magnification it looks uniform and slightly greyish but when treated and seen much magnified as it is when using the high power of the microscope, it can be seen clearly to consist of a fine mesh work of jelly-like substance in which lie a number of small granules of protein, starch, oil and other substances scattered through it. The protoplasm of a living cell also generally contains two or more irregular spaces which are filled with fluid which change and merge into each other to a certain

extent while the protoplasmic mass rotates. These are called the vacuoles, and vary in different types of cells, some cells having loosely packed protoplasm and a great deal of such liquid and others having denser protoplasm.

**Drawing of a single cell, showing its cell wall, protoplasm and nucleus.**

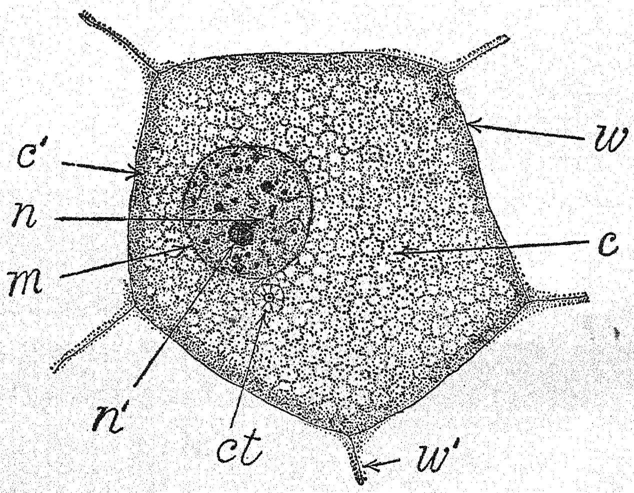



FIG. 17.

*A cell containing protoplasm of 2 sorts.*

c' *The outer denser cytoplasm*
c *The more vacuolated cytoplasm*
n *The nucleus with its own thin membrane m and the dense nucleolus n' The nucleus also contains various proteid and other granules. Close to it lies the centrosome ct*
w *Cell wall*
w' *Walls of neighbouring cells*

In the young cells of growing tissues the protoplasm is generally very close and granular. A diagram showing the essentials about cell structure is shown above in fig. 17.

Each single cell is a unit or entity and lives its own individual life within its cell wall, and therein whether it be thick or thin, definite or faintly marked the vital circulation of the protoplasm of the cell takes place. This is sometimes very slow, and hence difficult, almost impossible to detect, but in some cells it can be seen clearly and easily by those who have even a small microscope. The easiest way to see the circulation of living protoplasm is to take the purple hairs from the flower of Tradescantia. Without any dissection such as is necessary if solid tissue is chosen, all you have to do is to separate the hair cells one from the other and prevent them overlapping on a glass slide. Then, under the microscope you should see clearly the slow and definite rotation of the protoplasm in each cell round and round within its own cell-wall. Within the cell the nucleus attached by more or less definite filaments of protoplasm to the cell-wall tends to remain more stationary than the rest. There is, of course, no heart or pumping structure within an individual cell, and the life processes which originate this circulatory movement are among the mysteries which science cannot yet fully explain.

In quickly growing tissue the cells are frequently dividing and multiplying. They do this not by a simple dividing in two as one would divide a cheese with a knife, but the preliminaries of tissue growth by cell division are the result of a marvellously elaborate process which is gone through by the nucleus. This will be considered again in connection with "Reproduction" in a later chapter (p. 166), but must be mentioned now because it

is the mode of tissue growth and shows the great importance the nucleus plays in the life of every cell. In this process we have the most marvellous and the most elaborate spontaneous internal movement which occurs in living cells. Within the cell about to divide, the nucleus breaks up into definitely paired little units called the

**Diagram of the cell wall and nucleus of a dividing cell to show six of the stages through which the process passes.**

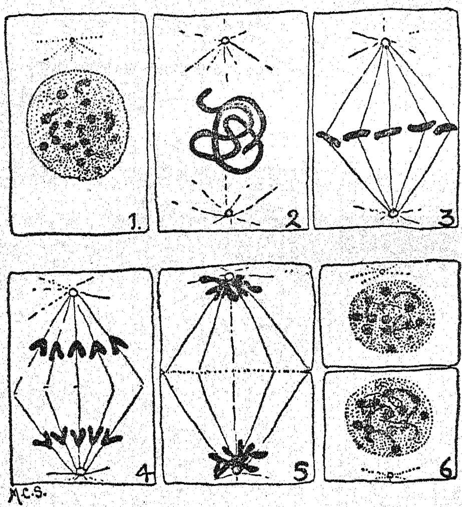



FIG. 18.

chromosomes. These go through an elaborate process, always the same, like the setting to partners and retiring of the dancers in a quadrille in a ball room. Their dance-plan is seen in fig. 18, but a fuller description of this process appears on page 102, Chapter X. It should not be forgotten that this wonderful dance of the chromo-

somes takes place *every* time a nucleus divides in the process of growth.

Further than this, if we enquire into the structure of the single cell more intimately, we will come to the realisation of entirely invisible movements within the protoplasm itself which must go on in the chemical rearrangements of the organic compounds forming the protoplasm. The chief chemical elements which compose protoplasm are, carbon, (the linking or joining element which unites one with the other by a process of linked affinity) hydrogen, oxygen, nitrogen and sulphur. In addition to these there are certain small quantities of the elements of phosphorus, chlorine, sodium, potassium, calcium, magnesium, iron and silica. But the play and inter-play of these chemical units is entirely beyond the range of the microscope, and leads us straight into the realms of chemistry and physics, and into mysteries of organic structure beyond human solution at the present time.

Let us therefore, remembering only the main facts of the chemical nature of protoplasm, return to the cells which we can see as individuals with the moderate magnification of the microscope. As we have already explained those, packed closely up against each other in the individual tissues, can only move in unison and not independently; but there are certain parts of the body in which the outer cells of a given tissue lie in contact, either with the fluid surrounding the tissue mass or with the outer air, as, for instance, the cells of the wind pipe, and of the bronchial canals from the lungs. The outer row

of cells thus limiting a tissue may have, and in some do have, the power of independent movement. This is particularly well seen in the limiting cells called the epithelium in the lining of the series of canals at the back of the nose. Behind the coarse hairs which we can see in the nostrils is the finer epithelium of the back passages of the nose possessing minute protoplasmic processes on one wall of the cells, that is the outer wall coming in contact with the air. The same is true of the trachea of the lungs and the bronchial canals. These fine processes of protoplasm which stick out from the walls of the cells are called cilia, and in the tissues abovementioned the cilia of the cells of the epithelium lining wave and move independently, yet more or less in a wave-like rhythm. They are seen in fig. 19.

**Two epithelial cells with cilia.**

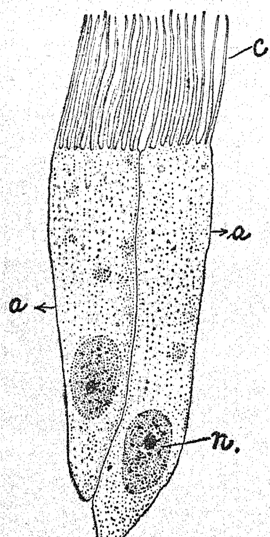



FIG. 19.
*c Cilia on the outer walls*
*a Walls adjacent to other cells*
*n Nucleus of the cell*

The use of these ciliated cells to the body as a whole is that if fractions of soot and particles of dust get down the lung passages, the epithelium cells excrete a little sticky mucus which catches them and then these waving cilia pass them on upwards and outwards by their wave-like movements until they are brought to the higher level

of the throat where they can be coughed up. The mechanism is something like that of a moving stairway, the dust particle being handed on by the wave-like movements of the cilia. Of course when one has a bad cold or bronchial attack or when one has been in a very dusty or dirty atmosphere, these cells tend to get clogged and over-worked, but in the ordinary way living in clean air, the cleansing of the bronchial tubes by the cilia is efficient.

Most tissue cells are adjacent to other tissue cells on all four sides, these ciliated cells are adjacent to their fellows only on three sides, and the fourth is the ciliated side which lies open to the channel of the air. So the independent movement is limited to the part of the cell on this *one* side only. Another place where important ciliated cells are to be found is in the lining of the Fallopian tubes in the female organs of reproduction. These catch the ova which are set free from time to time and tend to push or waft them downwards to the womb which they might not reach unless thus assisted.

There are not very many mobile ciliated cells of this sort in the body as a whole. Such specialised epithelium forms a very small part of the body.

There are four other types of cells with greater powers of individual movement, and these are the two kinds of blood corpuscles which move freely in the blood, and the reproductive cells, the ova and the spermatozoa, which have very much greater individual freedom.

The Blood Corpuscles have already been mentioned (p. 43) and it will be recalled that the red corpuscles,

although carried freely, as independent units floating in the blood stream, have no power to swim against the current of the blood and very little power to alter their own defined shape. They are *passive* moving cells.

**Side and front view of Human Spermatozoa.**

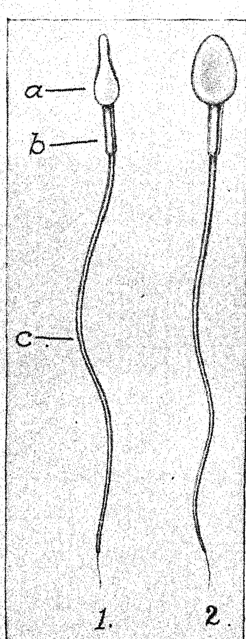



Fig. 20.

*Magnified* 1300 *times.*

*Though only consisting of one single cell, its shape is specialised and the parts spoken of as—*

*a* "*Head.*"
*b* "*Body*"
*c* "*Tail*"

The white corpuscles have a little more individuality and like the well-known microscopic animal, the amœba, can, to a certain extent alter their shape by putting out thick processes in the nature of cilia, making themselves into irregular star- or other shaped masses of protoplasm. They can do this to a certain extent as they travel about and perform their functions in different parts of the body. Their shape is not so definitely defined as the red corpuscles and their individual power of movement consequently greater.

Of the Reproductive Cells the *egg cell* or *ovum* moves freely, independently of any surrounding tissue, but it has no ciliated processes of its own by which it can definitely swim. It is wafted down the Fallopian tubes by the cilia of the ciliated lining of these tubes very much in the same

way as the dust particle is wafted along the bronchial tubes.

The *spermatozoon* or active male cell on the other hand has quite remarkable and unique powers of individual movement. Indeed among all the types of cells in the human body it is the only cell which has powers to be compared with those of the active free living uni-cellular organisms which are so numerous in the lower grades of life. In the human being each of the male spermatozoa (of which there are very large numbers, each very minute) has one long cilium or hair-like tail, which it can lash furiously to and fro, and thus propel itself rapidly through fluid as a fish swims in the water. A very much magnified drawing of this will be found on page 68, fig. 20.

More will be said later on about the capacity of this unique and remarkable type of cell, but in this chapter on the movements of individual cells, we need only remark that the spermatozoa stand out as unique in their activity and power of independent motion.

From the above few illustrations of cell movements it will be realised that the majority of the vast numbers of cells composing the human body after they have once begun their allotted work remain in their place and confine their movements to internal rotation of their protoplasm each within its own boundaries, and to wave-like impulses which may pass through them in unison. Each individual cannot move out of its own allotted place unless it be a specialised wandering cell.

## CHAPTER VII.

*Daily Replenishing—Feeding and Digestion.*

EVERYONE knows that we, in common with the larger animals, require to eat not only daily, but several times a day, and that this is such a strong and instinctive need that our natural craving for food becomes very powerful and even painful, if thwarted.

If we are very tired our need for sleep may overmaster us so that we fall asleep even at our work. We can do this because sleep requires nothing from the outside, and is attainable by the concerted action of the body cells themselves. But food requires co-operation from the outside, and the addition to our systems of something from our environment. Hence the human body cannot feed itself without taking into itself some of the various substances from the outer world which it can build into itself.

In this respect the animal body differs in a very important way from the plant body. Although both are built up of many small tissue cells which require nourishment (principally, although not entirely, with substances composed of carbon compounds) the plant body can take the necessary carbon in gaseous form out of the atmosphere and, building this simple compound up into sugar and starch for itself, can nourish its cells by carbohydrates manufactured within its own body ; the animal,

however, although needing carbo-hydrates on an even larger scale than does the plant to provide the animal *body warmth*, as well as nourishment, is yet incapable of manufacturing carbo-hydrates within itself. Every animal has to depend on either animal or vegetable food for its source of carbo-hydrates already made in such a form that with very little modification they can be assimilated and used by the animal cells.

This distinction in the method of feeding is of vital importance, and results in a profound dependence on the part of animal life, (and human life in particular) on the life activities of the vegetation. If it were not for the ceaseless work done by the green plants around us, which capture carbon-dioxide and manufacture the simpler forms of carbo-hydrates, none of the higher animals, and man himself could not exist. Whether we eat vegetables, bread, meat, fish or bird, we are getting the carbo-hydrates manufactured by plants at secondhand, for the fish, the bird or the animal we eat have all got their carbo-hydrates either directly from vegetable food or from some other animal or fish which obtained it from some vegetable.

Of course, our food does not consist only of carbo-hydrates. Various compounds, which contain nitrogen in addition, and go by the name of proteids are also most important, and also *in common* with the plants and lower animals, we need a certain amount of mineral matter in our food, as well as a large quantity of water. But carbo-hydrates form a large and indispensable part of our food.

The impulse to eat is so strong within us that, when hungry, a human being will eat almost anything which is at all in the nature of food, but in the ordinary way, even though having a good appetite, nature tempts us to eat by the appetising and pleasing smell which first assails the nostrils. So that when we consider the whole process of feeding from the beginning, we must take into account the sense of *smell* which resides in the nose (see also page 131). In connection with feeding the sense of smell is particularly important, because the stimulus of a pleasing smell makes our " mouth water " and thus summons the attention of the cells which prepare the digestive juices, not only in the mouth but lower down the food canal, and warns them to be ready for the food which is expected to follow. In a wild animal, of course, the sense of smell is particularly important, being the only test the animal can apply to its food to find out whether it is wholesome or poisoned, or whether in other ways it is suitable or unsuitable for it to consume.

In spite of some use of our sense of smell civilised man and particularly children are much more trustful than animals, and generally take what looks nice or smells pleasant at the table without sniffing cautiously at it to see whether it is poisoned or likely to be injurious.

Most of the *food* we eat is solid. Such things as soup, orange juice and milk appear to be liquid and in the main are so, though they hold some solid very finely divided in suspension in liquids. Now *solids* are of no use to the many minute cells all over the body for whose life-requirements the food is ultimately needed. All the

nourishing molecules of food which they can use must reach them in solution or fine suspension in liquids. As we have already noted, neither solid food nor ordinary air can get past the special lining of the inner canal which insists on *liquids only* passing through its cells. Hence the first thing to do with the food we eat is to make it soluble. This is what we call digestion. And as food consists of a great variety of compounds, some very tough which take a lot of pounding and treating before they become liquid or soluble, the processes of digestion are lengthy and various to deal with the different kinds of food substances.

The food once placed in the mouth the processes of digestion begin. In the mouth we prepare the food for digestion by the way we moisten it with saliva and by the grinding and biting action of the teeth in the upper and lower jaws. The lower jaw consists of a bone separate from the rest of the skull, but attached to it by strong ligaments. These ligaments are elastic so that the jaw can move freely up and down, and somewhat from side to side in the act of chewing and masticating. All the while this pounding and tearing by the teeth is going on, saliva is poured out from the salivary glands and moistens the food as it is chewed down into a pulp. It is very important, particularly that starchy food should have been thoroughly pounded and mixed with the saliva for that is the first stage of that particular part of the digestion which turns starch into soluble sugar. The entrance to the food-canal is seen in fig. 21 showing the teeth, tongue and back of the throat.

We are tempted by nature to go on with the useful process of mastication in the mouth because we enjoy the pleasant *taste* of good food and many foods improve in flavour as we hold them in our mouths. To appreciate the taste we have special structures on the surface of the tongue (see also p. 136). Digestion is a very complicated process which consists in the modification, partly by breaking down and slowly altering the complicated molecules in the food in such a way as to render them soluble and able to pass through the walls of the tissues lining the alimentary canal so that they may be absorbed and carried round the body in nutrient solution. Sugar which is quickly soluble, and meat juice are among the quickest to digest because they are already in a soluble state; but particles of starch for instance require warmth and the slow action of what are called "enzymes" to change them into a soluble form, a kind of sugar. People who bolt their food or who hurry over their chewing too

**Teeth, Tongue and Tonsils.**

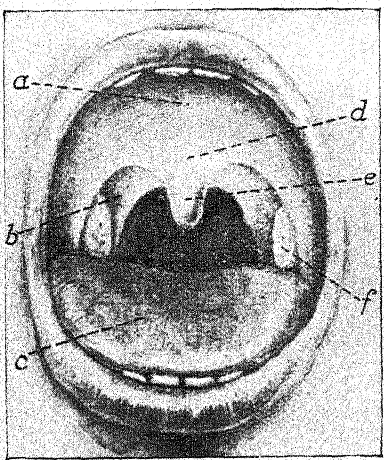
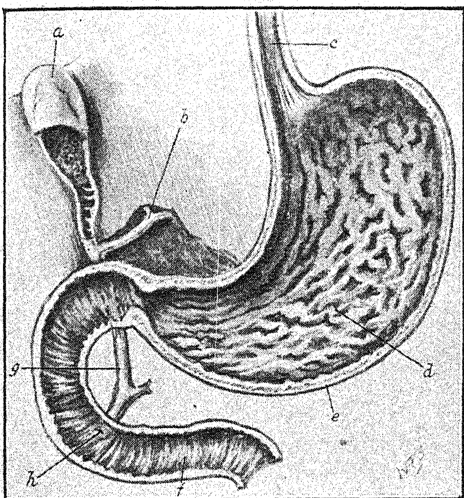



FIG. 21.

*a Hard palate*
*b Posterior pillar of the fauces*
*c Tongue*
*d Soft palate*
*e Uvula of tonsil*

much either waste part of the food they swallow or give themselves chronic indigestion, which is a double waste, firstly because the food does not get assimilated properly, and secondly because the consequent pains and general disturbance have a weakening effect on the whole system.

**Stomach and Gall Bladder with ducts, front view.**




*a* *Gall bladder partly cut open*
*b* *Hepatic duct*
*c* *Gullet, or œsophagus, as it joins on to the stomach*
*d* *Stomach cut open to show the muscular corrugations*
*e* *Outer wall of stomach*
*f* *Intestine with corruoated muscular wall*
*g* *Common bile duct*
*h* *Opening of pancreatic duct into intestine*

FIG. 22.

When we have finished chewing we swallow the softened mass of food, and then the ingenious little device at the back of the throat (see also fig. 33, Chap. X, p. 132) and a complicated contraction of muscles prevent the food going down the windpipe into the lungs. It passes down the wide canal of the throat, down the gullet and into the stomach. The position of the stomach in relation to the

other organs you can see in the general diagram, page 78, fig. 23, and in the atlas, plate II, behind 7 and 8.

The stomach is an enlargement of the alimentary canal in the form of a rather irregular oval bag which lies nearly centrally and across the main part of the body, and which has very elastic walls with a strong power of muscular contraction. This is seen in the simple diagram page 78, fig. 23, *d* which shows the stomach in relation to the whole digestive tract. On a larger scale, and cut open, it is shown on page 75, fig. 22, in which the ridges of the contracting muscles are seen on the inner side of the stomach wall. In the stomach digestion is carried on to a further stage and the stomach walls have scattered about among their lining cells small glands, which pour out solutions of digestive fluid. While this is going on the muscular movements (called peristaltic movements) toss and churn the food about until it is thoroughly well mixed, and the juices act on the food substances, breaking them down and altering them in the necessary ways.

Solid food remains in the stomach quite a long time, and indeed the process of digestion lasts three or four or more hours, varying according to the nature of the food taken, but generally lasting with a good overlap until the time when the next meal is due. So that, although we only eat three or four times a day, nevertheless nourishment from the replenishing particles of food is passing slowly into solution and being circulated round the body very nearly all the time.

After some time in the stomach what remains of the solid food is pushed down by the contracting walls and

the general movements from the lower end of the stomach into the long tubular extension, the intestines. These lie coiled backwards and forwards on themselves for a very great length, (see fig. 23 and plate II) and altogether nearly fill the lower portion of the soft central part of the body, and along this whole length the food has to travel and is being acted on further all the way. The small intestines are about 20 feet long when pulled out. At their lower end the intestines connect on with a wider tube, a portion of the intestine called the lower or large intestine about 5 feet long which takes a sudden upward turn and then runs across the centre of the body just under the stomach and down the other side again to conclude in the short straight portion called the rectum. This leads to the outer opening which is closed by that circular muscle, already mentioned, which keeps the anus closed except when natural requirements cause it to open at will.

All through the intestines still further and long protracted digestion goes on and is assisted by various juices and secretions, which are poured into the tube of the intestines. In particular there is the important secretion coming from the liver, which is stored in the gall bladder (a small oval organ in the liver) the bitter nature of which is well known, and which gives rise to the well-known phrase "Bitter as Gall." This organ (see fig. 22, *a*) is composed of a group of cells specially designed for storing the manufactured gall, which they pour down the gall duct (fig. 23, *g*) into the upper part of the small intestine, through a small opening at *h* fig. 23.

**Diagram of Alimentary Canal from mouth to anus.**

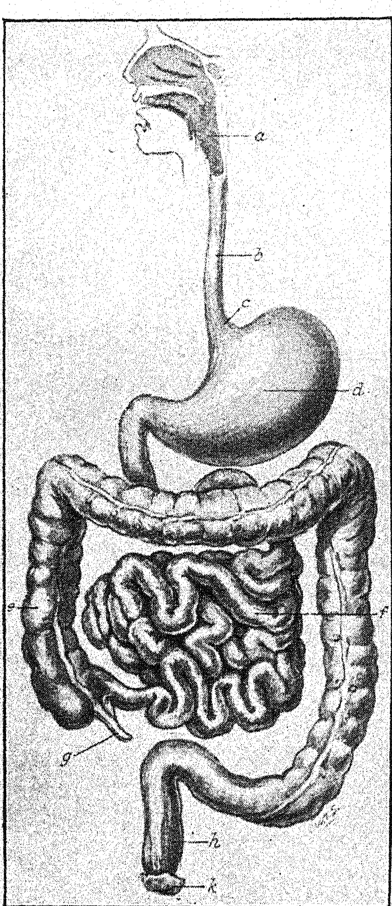



FIG. 23.

*a Top of alimentary canal*
*b Gullet or œsophagus*
*c Entry of œsophagus to stomach*
*d Stomach*  *e Large intestine*
*f Small intestine*  *g Appendix*
*h Rectum*  *k Circular muscle around anus*

The largest and most important organ which has connection with this part of the digestive tract, is the liver. The liver is partly a storage organ, the cells of which are specialised to concentrate a characteristic kind of sugar from the already digested food, and partly an organ for the secretion of bile, which is one of the most useful digestive juices. It also gives rise to other subtle secretions, helps to clear the blood, and to preserve the body heat.

The liver is one of the largest and heaviest organs in the body and its dark crimson texture is both soft and firm, the cells richly packed with food material and the whole interspersed with fine ramifications of the blood vessels. The old phrase: "Is life worth

living—All depends on the liver" has a great deal of truth in it in its purely materialistic sense, and those who are "liverish," whose liver and bile ducts do not act properly suffer many of the minor inconveniences which go with indigestion and that uncomfortable feeling of swimminess in the head which precedes sickness.

Nearby is the pancreas, another special organ which makes the pancreatic juice, a secretion of a different chemical nature also having its work in assisting to break down and digest parts of the food.

The long lengths of the small intestine, coiled on themselves are held in place by a fine membrane, seen spread out in plate III. Down the complicated length of the intestinal tube the food is propelled by contractions of its muscular walls until the small intestine merges with the large intestine, along which the remains of the food are carried further.

In Fig. 23 you will see a little tail-like end at the foot of the large intestine where it joins to the small intestine, and that is the Appendix. This is a curious remnant of an organ which appears to be no longer of use to us, and indeed which is a little blind alley opening out of the alimentary canal. In it sometimes grape stones, and other indigestible food will lodge and give rise to inflammation of the appendix. When things go wrong with this small sac, we get the well-known disease of Appendicitis, the cure for which is very often the cutting off of that useless little appendage.

By the time the remaining mass of food has passed down both the small intestine and the large intestine, and reached

the rectum, hours have elapsed and so many chemicals and so much churning has taken place that the whole is reduced, or should have been reduced to a soft pulp from which most of the nutrient goodness has passed through the soft absorbent walls lining the long alimentary canal. As it is absorbed it is available for circulation round the body to all the tissue cells wherever food is required. What remains is no longer useful, and enters the rectum when it should be evacuated at once. Modern people tend to hold it in the rectum and evacuate at set times. This should be seen to not less than daily, for the walls lining the rectum are also absorbent to some extent and tend to absorb the water and some of the remaining juices from the mass, and by this time it is unfit for absorption and the system suffers instead of benefitting by such contact. The right thing for the system is an immediate evacuation directly the soft mass reaches the rectum.

Most of the digestive organs and all their associated structures and tissues are controlled by the unconscious nerve centres, the so-called "sympathetic system" and properly our consciousness ought to feel little or nothing of their work. But if the food proves indigestible, and if any of the organs closely concerned with digestion are out of gear and not working correctly, then the nerves which ramify closely all over the alimentary canal convey a message to the conscious brain cells and the central system feels either discomfort or pain or a series of disturbances which may seriously affect some of the other organs. For instance we get "biliousness," and this

causes a headache in the brain, affects the eyes, and may even affect the power of balance. A person who is about to be very sick, for instance, cannot stand and feels such "swimminess" that he must lie down or he will fall.

These extreme effects, of course, only arise when something is seriously wrong. In the ordinary way the proper actions of all the organs are so interlocked that the processes are not recorded at headquarters at all. In modern so-called civilisation, however, we know much more about imperfect digestion than we should. An undue strain is put upon us not only by the artificial and unnatural foods which we eat, and the rich seasoning with which they are prepared, but also by the many subtle poisons which are introduced or interfere with the proper action of the digestive juices. It is easy to understand that if a chemical put into meat prevents it going bad, that means that it prevents bacterial and enzyme actions, and as some forms of bacterial action take place in addition to the chemical actions of various secretions during digestion, naturally these preservatives act in the same way within the digestive tract as they do outside of it, and the preserved food lies undigested within, or is more difficult to digest than it should be. Or, what is quite as serious, is "preserved" till past the proper place in the digestive tract for that type of food to be dealt with and then goes bad further down. In addition to these injuries the chemicals in the preservatives may act as positive poisons to the human system even if taken in what seem very small doses. Such a positive poison is boracic acid, often used in small quantities, but the many

small quantities daily used may add up to a detrimental amount.

The phenomena of digestion remind us of one of the characteristics of the body which is very interesting and important, namely, that when all is going well in the many "factories" and tissues under the control of the system of unconscious nerves, and all are in working order, the higher brain centres and the conciousness of the human being are set free to concentrate on all the manifold interests and phenomena outside the body; but when things go wrong, then the offending or suffering organs have the power to send definite messages to headquarters and the central nervous system of the human being is either diverted or entirely occupied with the internal disturbances or the anarchy which is going on, and thus is hindered in its relations with the outer world.

## CHAPTER VIII.

### *Daily Replenishing—Feeding and Excretion.*

THE useless portion of the solid food eaten, simply passes out of the alimentary canal; in addition to this, the complicated processes of feeding the tissue cells involve the disposal of the waste material they themselves make. Waste products arise from the actual cell-life, for each cell has been burning up and using the soluble food brought to it, so that every cell in the body is a source of minute but steadily produced waste material. This has to be got rid of. And the various forms of waste are disposed of in several distinct ways.

As we already saw in the chapter on breathing, (see *ante* page 21) some of the waste in the form of carbon-dioxide comes out of the body from the lungs in the breath, other waste comes out through all the minute pores in the skin secreted in the form of invisible perspiration, which leaves a vapour on the skin in the form of sweat poured out by the glands, (see Chapter VI). The greater part of the waste product from the minute tissue cells, however, passes into the blood and lymph, and is ultimately pumped round the body. On its way it passes through two special organs which form clearing houses for the blood, and which are called the kidneys. These will be dealt with in some detail as they are interesting and important organs, and they keep a steady hand

**The apparatus for cleansing the blood:—the two Kidneys and Bladder, with the blood vessels, etc.**

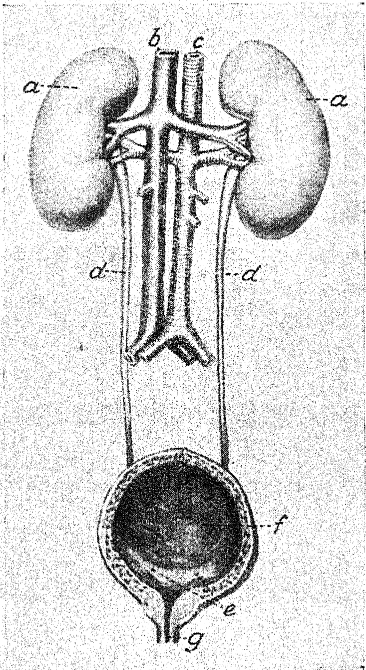



FIG. 24.

*a Kidneys, complete (not cut open)*
*b In erior vena cava (large vein of kidneys' blood supply)*
*c Aorta (large artery of kidneys' blood supply)*
*d Ureters (tubes carrying liquid from the kidneys to the bladder)*
*e Ureteric orifices (openings of these tubes into the bladder)*
*f Bladder cut open*
*g Urethra (tube leading away from the bladder, cut open)*

on the waste produced in the whole bodily system. The kidneys filter waste out of the blood and pass it away in a dilute solution to accumulate in a special organ called the bladder. Thence it is disposed of from time to time by the conscious direction of headquarters.

The kidneys are two in number, one lies on each side of the body towards the back in the region of the waist. In most people, one is slightly larger than the other—generally that on the right side is the larger although not always. You will see the two kidneys and the blood vessels and tubes associated with them clearly shown in diagram 24. They are also shown coloured brown, as in life, and

in their place in the body cavity, in plate IV, 22, 13 of the Atlas. Arteries and veins attached to them are partly cut away, but the main trunks show at *c* and *b* in fig. 24. You will notice that running down from the central portion of each of the oval kidneys is a long narrow tube, *d* in fig. 24 and 15 in plate IV. That is the canal carrying the stream of liquid prepared by the kidneys down to the bladder for storage. The round rather large organ at the base of the trunk, 19, plate IV, is the bladder. A diagram of this appears on page 84, where the bladder *f* is cut open and the small holes by which the fluid enters are seen at *e*. The exit from the bladder is an important tube, part of which is shown at *g* cut across. It is called the urethra and is present in both man and woman though somewhat differently developed at the exit, and is important as being one of the very few exits and entrances in the body.

**One Kidney cut open to show :—**

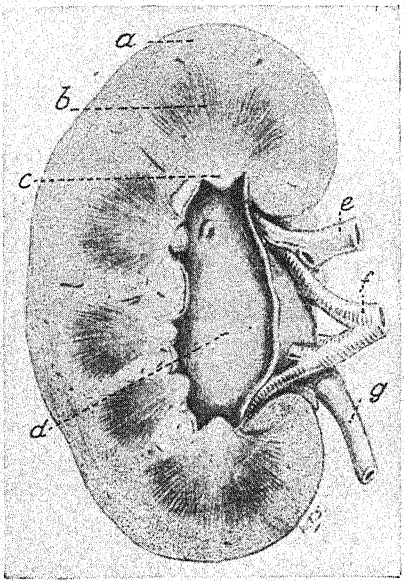



FIG. 25.

*a* Cortex — *e* Renal vein
*b* Medulla — *f* Renal artery
*c* Pyramid — *g* Ureter
*d* Pelvis or equity of the kidney

Each kidney is outwardly something like a large bean, about four inches long, smooth and oval, with the convex side somewhat pleated and crinkled. Kidneys are very similar in the human being and in some of the lower animals. Sheep's kidneys are frequently to be found in the kitchen, and it is possible to cut them in half and dissect them sufficiently to understand their structure fairly well. Even in a kidney that has been cooked you can see fairly clearly the different zones of tissue in it. Each of these consists of cells, each of which has its own special part to play. There is the outer, rather firm material which is called the cortex and then the somewhat oval pointed papilla-like portions of the medulla, and the so-called pyramids, in which the arrangement of the cells brings the very complicated network of fine blood carrying capillaries in touch with those special cells of the kidney which filter out the waste material from the blood. These are grouped to form minute convoluted masses, called malpigian capsules and are seen in the diagram page 87. Immense numbers of them are packed into the cortical layer.

The liquid containing the waste matter they collect from the blood drains through the fine tubes into the central cavity of the kidney, called the *renal pelvis* (*d*, fig. 25, p. 85) and from that runs down the tubes of the ureter for storage in the bladder.

The amount of liquid which passes through the kidneys is very considerable, depending of course largely on the amount drunk, and also on the kind of weather. In hot weather the sweat glands of the skin give off much more

water vapour than is given off in cold weather, so that in hot weather a less proportion of the liquid drunk passes through the kidneys (and therefore into the bladder) than passes in cold weather. On the other hand most people tend to drink more in summer than in winter, and, therefore, the kidneys have to deal with approximately the same amount of dissolved waste products both summer and winter.

**A single "Malpighian Capsule" from the cortical layers of the Kidney.**

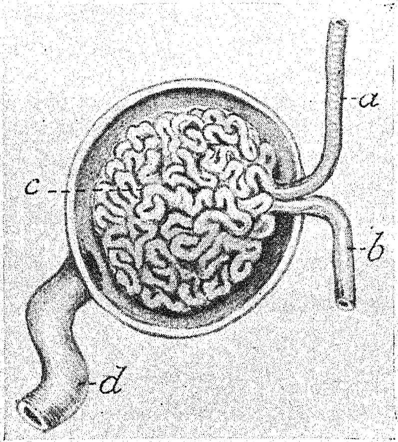



FIG. 26.

*a In-going capillary* *c Glomerulus*
*b Out-going capillary* *d Tubule*

The kidneys filter out of the blood various compound salts of uric acid which give the water excreted by the kidneys a straw or amber colour, according to the amount of dilution. The liquid is called urine and contains urea. If the uric salts are concentrated beyond a certain small percentage, the bladder is irritated and discomfort and even disease may arise. What happens in the ordinary healthy way is that the kidneys through the malpighian capsules are steadily withdrawing the waste products from the blood, dissolving them in water and pouring them down through the tubes into the bladder at the base

of the body, which acts like a reservoir and collects the fluid until it contains a certain quantity. When the bladder cannot comfortably hold a further amount, or when the irritation set up by a too strong uric solution causes an artificial sense of fullness, the muscles of the tube leading from the urethra relax so as to allow the fluid to pass out. Those who drink too little and whose urine therefore has too strong a percentage of uric acid in it irritate the bladder and thus force the bladder to act too frequently and for too small amounts. A curious apparent contradiction then arises, and those who complain of having to pass water too frequently are told to drink *more* water, then this trouble immediately ceases. The larger amount of water dilutes the uric salts, and the bladder, being no more irritated by a strong solution can retain a larger quantity a longer time and under better control from headquarters.

The muscles which control the bladder and urethra are voluntary muscles, that is muscles controlled by the brain, and therefore they can be relaxed or contracted at will, although this control is only voluntary when things are normal and only to a definite limit. If unnatural pressure is put on these muscles then they cannot act properly and sometimes artificial tubes have to be inserted to put things right.

The tube which leads away from the bladder and which you can see indicated in the diagram *g*, fig. 24, page 84, shows the opening at the base of the bladder into the canal called the urethra, and its point of final exit differs in the two sexes. The tube of the urethra is short and

simple in the woman and opens directly as seen in diagram 49, page 190 (see also Chap. XIX), but in the male the short urethra opens into another tube (used also for a second purpose) and is carried to the end of the special external organ, characteristic of men and boys (see Chap. XVIII, fig. 47). It should, however, be fully understood that in both sexes the urethra and its opening are entirely separate and distinct from the sex organs, although their point of exit lies so close that often ignorant or misinformed people confuse the two functions, and hence a sense of sex-repugnance has sometimes grown in people's minds by this confusion and a quite false idea is prevalent that these organs of sex are like the kidney and bladder, only organs of excretion. This is, of course, a very serious mistake, and sometimes colours the attitude of those making it, and causes them to place sex in a wrong light. It is very important therefore that the course of the tubules should be properly understood and the functions of the excretory organs realised as quite different from those of sex.

The special excretory organs of the *skin* are also very interesting and important, but as we are devoting a chapter to the skin we will consider them there (see page 112).

The wholesome body should not only be clean and free from accumulated waste matter both inside and out, but should have a sweet and pleasant bodily odour; particularly when the sun shines upon it. When this natural human sweetness (as distinct from scents artificially added) is absent the conscious brain of the body's owner should

consider the conditions under which the inner organs are forced to work, and should see whether they are not being clogged in some way and prevented from keeping themselves and each other as pure and sweet as they should be. Lack of air, lack of water, lack of sunshine and too much food, too many clothes and too late hours all tend to soil and clog the cell communities within us.

## CHAPTER IX.

### *Daily Replenishing—Warmth and Sleep.*

THE living human body is warm to the touch, except where temporarily the outer skin of the hands or other exposed parts may be chilled by the wind or the low temperature of the surroundings. Within there is always a certain amount of body warmth, which is well regulated to be nearly uniform throughout the whole extent of the body. In the grown man or woman, the normal temperature is 98.4 degrees Fahrenheit, but some people vary a little being generally a point or two of a degree higher or lower than this, and tiny babies have a somewhat higher temperature when kept as comfortably warm as they should be.

It is a remarkable thing that such a uniform temperature should be maintained by a healthy body, and indicates an extraordinary power of adjustment and balance between many remote organs. The body experiences great variations in the external temperature, there are also processes going on inside the body tending to make it either hotter or colder ; but before they can take general effect almost instantaneously other organs react so as to keep the temperature of the whole at the normal. For instance the hot weather and the bright sun of our summer days would tend to warm up the human body, but that very warmth stimulates the production of more

perspiration from the whole surface of the skin and the invisible evaporation of that perspiration tends to cool the body down. Most people well know how cooling is the effect of the evaporation of water or other liquid, and from the human being the amount of liquid to be evaporated and therefore the degree of cooling resulting from this evaporation varies in such a way that as the outer temperature tends to rise, the evaporation tends to increase and keep the body heat normal.

A parallel effect is seen when heavy clothes are worn. If one has too many heavy or thick folds of clothing over the body, it will perspire and tend to cool itself off. As in this way the body's natural intelligence has been thus interfered with, it may give rise to a chill, which may be serious. A body quite naked and unclothed in the open air is much less liable to " catch a cold " from a chill than one which has been overclothed to the extent of accumulating damp perspiration which cannot evaporate quickly enough through the clothes.

But all such outer sources of heat as clothes and the weather play only a minor part in the production of the steady amount of warmth which characterises all healthy human tissue. The main source of warmth for the body is the series of invisible chemical reactions of the combination of oxygen with the carbon containing chemical molecules in the body cells themselves. Those who have studied chemistry know that the oxidation of a carbon containing compound may take place in many forms, but when on a comparatively big scale and in a concentrated manner it is seen as burning, for instance, in a lighted wax

candle, the oxidation gives rise to a very definite and localised form of heat, the flame. The heat of the flame of a candle that is enough to burn the human flesh or boil a small quantity of water depends entirely on the intense chemical energy given off by the oxidation of carbon compounds, that is to say the union of oxygen and carbon set free in the form of carbon dioxide gas.

Now in every cell of the living body a similar oxidation or slow burning is going on incessantly and it is this slow burning or oxidation of the carbon compounds (the oxygen, you remember, is provided from the outer air through the lungs and carried round in the blood corpuscles) which are woven into the complicated molecules of the cells themselves. At no tangible point does the heat become intense enough to burn anything visibly and on a large scale. Although, if we imagine the remote and ultimate structure of the carbon dioxide molecule, it is obvious that the same degree of action must take place within any one molecule as originates in any *one* molecule of a burning candle, but in living tissue the individual cells are so minute, and their activities scattered and separated in such a way that there is no charring or anything in the nature of what we commonly speak of as burning. The constant oxidation of molecule by molecule within the living tissue gives rise to its steady warmth. In spite of this civilised human beings do not lead sufficiently active lives to live in such a cold climate as that of northern Europe without some protective clothing, and most of the time we smother ourselves in clothes. But whenever the temperature is

sufficiently warm as on a sunny midsummer day, the body is immensely healthier and more physiologically happy if no clothing at all is worn or only the very lightest and airiest. One reason why everyone likes to go to the seaside is because the small bathing dress allows the outer air to play over the limbs and to give that natural glow and pleasure in the touch of moving air that the skin should feel. In the winter, however, and at night, particularly when we are lying down in the horizontal position (when radiation from the body is greater than in the vertical position) covering is necessary. The clothing, however, does not itself bring any warmth to the body, which continues to derive all its heat from its own oxidation. The clothing only holds the warm air which otherwise would evaporate off the body, and by preventing its escape stops the continual leakage of body warmth which would otherwise take place in a cold atmosphere.

A slight amount of control of local temperature from headquarters, otherwise than by the application of clothes is possible, but on the whole the temperature is spontaneously regulated by series of nerves and muscular and vascular contractions and expansions, over which the central brain has little or no consciously exerted control.

Wherever the main mass of the blood stream tends to concentrate, however, the surface tends to be a little warmer than the rest of the body, and in most people the supply of blood is such that it is possible definitely to feel that it is acting specially in one or another part. For

instance, those who work very hard with their brains find that the blood collects in the skull, so that the head and forehead may feel hot and their veins somewhat swollen, while the feet get very cold. In contrast with this, directly after a heavy meal, when the main blood accumulation of the body goes to the digestive tract the brain may get tired, even to being sleepy, until the first rush of digestion and its claim on the blood stream has been satisfied. This sleepiness which most people feel in the middle of the day if they then have a heavy dinner, gives us the key to a certain extent to what happens in the ordinary way every night when we go to bed.

The mid-day sleepiness after food is not due to fatigue but is definitely due to the withdrawal of the blood from the brain and its concentration on the unconscious system of digestion in the abdomen. At night we sleep because of general fatigue, and when we sleep the blood tends to recede from the brain and to collect in the lower limbs and the trunk, and this rests the central nervous system by taking from it the power of definite and consecutive thought. That is why a sleepless person finds a hot water bottle at the feet so helpful because it tends to draw the blood down to the feet and distribute the body heat more uniformly, and thus relieve the excitement of the brain. Sometimes it will be noticed when one first dozes off, that in just a moment or two of sleep, feet which were cold at the time the sleeper dozed off, quickly glow with warmth. This is due to the relaxation of the tension of the local nerves and the more even distribution of the blood supply to the limbs.

Sleep is an item of the daily replenishing of the body's machine which is mysterious and difficult to discuss. It depends on no large and obvious structural point in the body, and it is only partly controlled by the will power. A few individuals here and there can say, "I will sleep at such and such a moment" and they are able to do so, but the majority of people only sleep in the calm and pleasantly warm and uniform surroundings of a comfortable bed, and at the end of a day of reasonable activity. Some can go for long spells without sleep, and others require every day much more sleep than such unusual people as Mr. Gladstone, who is supposed to have slept only four hours a night for many years.

A great deal of ignorance still surrounds our ideas of sleep, but one may say in the main that our regular nightly sleep is possibly a characteristic inherited from our very early ancestors who retired to the shelter of caves at night to be out of reach of prowling beasts, and having there nothing to do got in the way of using the time for rest. Many animals contrary to the habit of man use the night for activity and sleep all day; some sleep very little in the summer and sleep all through the winter. So that, although in the ordinary well regulated human being at present, replenishing sleep takes place at night, this is by no means so fixed or fundamental a physiological habit as the others we have hitherto discussed, and it varies immensely more than the more definite functions of such organs as the heart or lungs.

The physiological effect of sleep is cleansing and restorative. During activity the oxidation and excretion

of waste by the cells goes on rapidly. In all mature cells that are acting, contracting and expanding or secreting, or performing any of the subtle movements which characterise their particular type of tissue not only are carbon dioxide molecules being produced, but the cells are accumulating minute quantities of waste chemical compounds. The waste organic compounds containing nitrogen, accumulate in the interstices between the living cells and tend ultimately to clog and poison them if not cleared away. For a certain amount of time the natural clearance goes on and the balance is maintained, but from early morning as the day progresses, gradually these products accumulate rather faster in the whole system than they are removed and thus they tend to overcharge the blood and lymph. Then the need for rest and sleep is felt by a kind of "all-overish" muscular exhaustion which expresses itself by yawning and a desire to lie down and rest, the yawning being due to an ineffective effort on the part of the lungs to take in more oxygen. Then after a muscular rest, and the slight redistribution of the circulation of the blood during sleep, these waste products are cleared away and by the morning the man or child should wake with every muscle and tissue cell in tone ready to spring into activity at the command of the higher nerve centres.

In spite of the natural reasons for the alternation of regular periods of activity and periods of rest, in an emergency the will power can flog the organs into doing what they would not naturally do. How far the nerve centres then can control and make up for lack of natural

rest and sleep is not yet known, but feats of endurance almost incredible in their extent have been accomplished under the stimulus of intense determination. These are generally paid for afterwards by an overstrained or poisoned condition of the whole system.

While a child is growing and the tissues are forming rapidly and are not yet fully adapted to work, very long hours of sleep are necessary. In old people the hours of sleep tend to become shorter and less urgent, until in the very old whose stamina has begun to wane, long hours of sleep are not so frequent, but give place to many short dozes which rest the easily tired and worn out nerves and muscles.

One ought to say a word about dreams, but although a very fascinating subject, it is one which takes us over the borderland of a simple scientific description of the body's functions into those difficult and controversial regions that we enter when we begin to touch on man's mental and rational life.

## CHAPTER X.

*Daily Replenishing—Growth.*

IN every nursery, school and college, the outer facts and the general ideas of growth are always present. The newly born baby grows rapidly, and after a year has more than doubled, indeed has nearly trebled his size at birth. Inch by inch the toddler in the nursery shoots up to be a school boy.

However unlearned the observer may be, he or she knows very well that the result of this growth depends on the food eaten, and if a child is not properly nourished growth will either be slow or incomplete. Yet all the marvellous intricacy of secret development that lies beneath the outer smooth skin and really represents the scientific facts behind growth are hidden from human eyes. They include one of the most marvellous qualities in cell behaviour, a process so complicated and so rhythmically beautiful and regular that we must spend some little time considering it. Before doing that let us just emphasise the fact that growth, although externally it appears to be a mere swelling and enlargement of organs that are already there, really involves the creation of new cells interspersed among those existing. The baby, young as it is, has fingers and thumbs with little nails and knuckles all complete, and without enquiry one might assume that just as a rubber animal is complete and can be

enlarged greatly by blowing air into it and stretching the original rubber without increasing the amount of rubber in the animal, that a similar simple process went on in human growth—that the baby was elastic and the food it ate merely stuffed and stretched it out in the way that the air stretches the rubber animal, and that all the original substances were there ready to be stretched.

That, however, is not so, and what takes place in growth is an actual increase in the number of cells composing the body, new cells are formed, which place themselves in between the cells already there with such precision and such delicacy that the whole balance of the organs is not disturbed, and yet the number of cells composing them is increased.

The following simple comparison will give you some idea of what is going on. Let us imagine a little house made of separate bricks, mortar etc., containing eight rooms with windows and doors all complete and all very tiny, but the bricks more or less the size of ordinary bricks. Then imagine that a magician should slip in bricks between the bricks already built, all in a well balanced way so that overnight, let us say, there were ten new bricks slipped into the walls of each room, and the next night ten more and so on, without in the least disturbing the house, managing to keep the roof on straight and the doors and windows without any leakage or crack, and yet slipping in bricks which, by the time the magician had finished gave a larger house still only of eight rooms and with equally balanced doors and windows, but containing far more material, and a far larger

quantity of wall space, which had all been slipped in without giving the inhabitants a draught of cold air or letting the rain leak through the roof—an impossible house, of course, but a parallel to what is going on every day and night in the body of a growing child.

Growth takes place all the time, but it is evident that more growth goes on during the hours of rest and sleep than at other times, because when we are lying at rest there is not the same drain on the vital energy and on the food supply as there is when we are running about and using our muscles, but whether the growth is slow or whether it is rapid, growth of almost all the cell tissues of a human being takes place in the following way:

Any tissue, the liver, the heart, the muscles, the brain, or whatever it may be, contain, as we have already seen (*ante* page 2) groups of cells, each like each other, and each doing a definite piece of work. The cell, however much it may be modified in shape and appearance for this special piece of work, consists, as we saw (*ante* page 61) of a mass of protoplasm with its nucleus. Each cell, after having been formed, very soon reaches its own mature size. Sometimes a grown up single cell may be 1/1000th of an inch in diameter or 1/100th of an inch. Cells vary greatly in length and breadth and size and shape, but with a few notable exceptions such as the very long nerve cells, the size of nearly all cells is measured by 100ths and 1000ths of an inch, that is to say they are microscopic in size and invisible to the naked eye.

When any tissue or any part of the body is growing, the cells composing it increase in *number* and not in their

individual size after their own natural limit has been reached.

Now there are two ways in which cells may increase in numbers; one is by simply dividing in half, in which case the nucleus develops a kind of groove and divides, and the protoplasm rounds off, and so forms two nuclei and two portions of protoplasm, both of which soon reach their natural size. But this, which is called simple cell division, is not common in the tissues of the higher animals so far as we can discover, and even though it takes place in some tissues and on the part of some cells, we do not know that it is permanently satisfactory.

You will understand how difficult it is for people to see the divisions of cells under normal conditions in the human body. Only the rarest opportunity makes it possible to know what is going on actually in the living cells of a living person. We do know, however, that the majority of growing tissue cells both in plants and animals go through the very elaborate process called karyokinesis or mitosis. A simple account of this intensely complicated, interesting and important process is as follows:—

Among the concentrated granules in the nucleus (see fig. 27) is some very special material, which, in the ordinary way has no distinctive shape, but when the cell proposes to divide, it arranges itself into a long convoluted skein looking somewhat as would a few yards of wool wound into a rough irregular ball (see fig. 27, 2). This skein of material separates itself up into definitely shaped segments, each one of which is like the others. These frequently start as straight strips or segments, but

tend to curve into a more or less definitely horse-shoe shape (see fig. 27 at 4). These are so important in many theoretical ways that they have a scientific name and are each called a " chromosome."

One of the most curious things about the whole complicated process is that every species of plant and animal

**Six stages in the cell division (or mitosis or karyokinesis) of a dividing cell in growing tissue.**

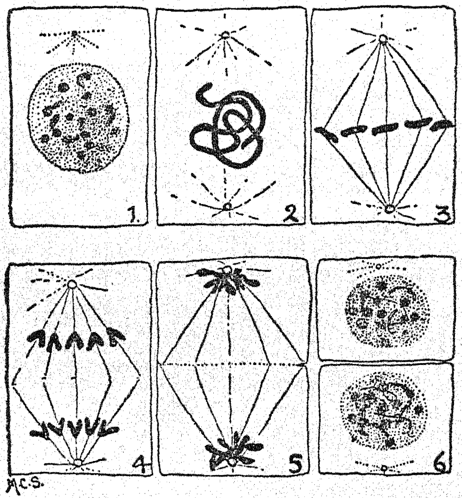



Fig. 27.
*For detailed description see pages* 102 *et seq.*

does this, and every species has its own fixed number of these chromosomes. That is to say, when the long skein of chromosome material breaks up in the lily to its thirteen separate chromosomes, it always breaks up into thirteen separate chromosomes, other plants have other numbers.

While in some animals it is a much higher number and in others a much smaller number it is only 2 in a very lowly worm for instance, and about 36 in echinoderms. In human beings whether negro, Chinese, or European, the number appears to be fixed and always the same, and is supposed to be 48.

While the chromosomes are individualising themselves inside the cell another process is going on, and that is the formation of two small faint star-like centres of very fine glistening white material with radiating threads of what is a refined and clear form of protoplasm. These two star-like centres then send their radiations across to each other until they form a spindle such as is seen in diagram fig. 27, 3, page 103. When the spindle is complete, there are a definite number of these fine radiating threads, and each comes up to the centre star, so that the whole is something like the lines of longitude on the globe running from the north to south pole. According to the chromosomes of the species so the number of the "lines of longitude" vary. Then what may be called "The Dance of the Chromosomes" begins, and these separate curved chromosomes move and place themselves round the equator of the spindle with their curved end towards the spindle (4, fig. 27). They then split in half in the way you might split a horse-shoe roll in half so as to give two horse-shoes, and then the two move slowly apart keeping in touch with the longitudinal lines of the spindle. They move further and further apart until they collect in groups at the north and south poles, as we may call them, of the spindle (5, fig. 27). Little lumps and swell-

ings collect along the middle line of the spindle until they form a solid zone through the whole equator. Meanwhile the protoplasm of the cell tends to round itself off into two groups, at the north and south poles; each group of the horse-shoe-like chromosomes, after remaining a while separate, tends to join on to themselves end to end and finally each group resolves itself into a twisted thread again. Hence there now are two groups of the tangled skeins of chromosomes. The skeins break up and become less and less conspicuous and more like a usual nucleus and then each of these two nuclei surrounds itself with its fine membrane, the protoplasm rounds off, and you have two cells resulting from the original cell (6, fig. 27). Each of these two new cells contain, as you see, a carefully mixed and divided half of all the chromosome material as well as of the protoplasm of the original cell. Then each of these two continues to grow, using the nourishment and food brought to it by the process described in Chapter VII, each increases in bulk until it is as big as the original cell, so that we have two cells of full size in place of the one cell.

If all the cells in all the tissue of any one organ were to do this in one night, then it would double itself in one night; but that never happens. Although the process of karyokinesis only takes a few hours, nevertheless, all the cells in one tissue never do this simultaneously. But a few cells sprinkled here and there in each tissue divide at one time and thus the whole bulk of the tissue increases slowly, and growth takes a long time.

One of the most marvellous secrets of life lies in the

fact that this elaborate and beautiful process of karyokinesis is almost identical in plants and animals. Although the cell walls differ to some extent as already mentioned, yet the protoplasm and the nucleus and this most important of all their capacities are intimately and remarkably similar. Life evidently has some fundamental similarity whether it appears in the human child, an animal, a tree or a flower.

Now when this process of karyokinesis or division to form the growth of tissues takes place in the ordinary way as described above it is called homotypic karyokinesis. I am sorry the words are so long, but there are no popular words for these facts as they have only been made known to humanity by scientific men and women, yet it is important they should be understood. Although ordinarily the general public is not told of these mysteries, nevertheless the slight difficulty of learning a few terms ought not to prevent everyone knowing and understanding such a vital fact about the secret of life.

This " homotypic " or " all-alike " karyokinesis is what takes place in the ordinary way in the growth of tissue. It is, as you will see a form of reproduction of the cells, that is to say where one cell was before the process, two cells were afterwards, but although this form of reproduction of the cells takes place it does not lead to the reproduction of the whole animal, and therefore when you look at it from the point of view of the life of the whole animal, it is only growth and not reproduction.

When reproduction takes place, karyokinesis sets in in special cells, but is a still more complicated process.

The young cells which are formed in the various tissues which are growing in this complicated way, each know what particular way they have to specialise, and each grows and specialises till it is like the tissue cell whose work it has to carry on.

Now as regards the external appearance of human growth. We know that it is much more active in the early years of childhood, and one or two points about the changes in the different ages and periods of life may be of interest. As regards the bones for instance:—The bones of a very tiny child are much softer and much more cartilaginous than those of an older person and their growth consists not only in an increase in the number of cells forming the bone substance, but an increase in the amount of hard tissue deposited in each cell, the so-called ossification which takes place. Between the soft cells forming the cartilage, certain centres lay down hard mineral matter composed of chemical compounds of phosphates and calcium etc, and as these accumulate they strengthen and make the hard portion of the bone. An unborn baby's bones are quite soft, a new born baby's are partly soft, and only as it grows do its bones get mineralised and hard.

Another special and very noticeable growth and peculiar development is seen in the teeth. A baby newly-born has no teeth visible, although in its little jaws the beginnings of the teeth are already there. The baby cuts his teeth a few at a time, generally the two front ones come through the jaws together, then the others one at a time until the time the baby is two years old he has his full set of first teeth. But although we see these baby teeth

in the jaws, they are not the only teeth the child has. Lying behind the visible gums inside the jaws are the roots and the first part of the development of the mature teeth, and the cells that contribute to their growth are laying down a little at a time the hard material which forms the solid part, and then the outer polished enamel of the teeth, years before they appear (see fig. 28).

**Drawing showing the jaws with the first teeth in use, and the second teeth growing below them ready to push them out.**

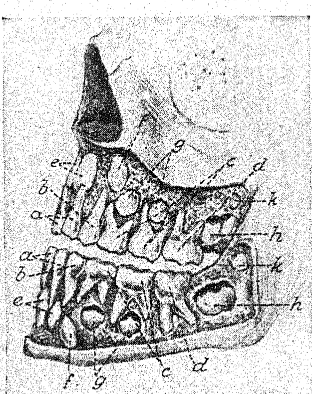



FIG. 28.

*a Incisors* (*1st dentition*)
*b Canines* (*1st dentition*)
*c Milk molars* (*1st dentition*)
*d 1st or 6 year old molars* (*2nd dentition*)
*e Incisors* (*2nd dentition*)
*f Canines* (*2nd dentition*)
*g Premolars* (*2nd dentition*)
*h 2nd molars* (*2nd dentition*)
*k 3rd molars or "Wisdoms"* (*2nd dentition*)

Most people are fully grown when they are twenty-five, although some may even grow in bulk and stature until they are nearly thirty. One of the last changes in development that takes place is the final hardening of the bones in the skull. The skull is different from all other bones in being very slow to develop, and some points about it may be of interest. The bones of the skull (see fig. 50, page 203) have crinkled, jagged edges which interlock and so fit into each other firmly and help to hold the whole oval of the skull in shape, but in a tiny

new-born baby the crown part of the skull is not yet hardened with its full amount of bone tissue, and although the baby's skull is covered over with skin, and often with hair, and it is firm enough for careful use, still just in the centre there is a soft region in the top of the baby's head where the bones have not yet joined together, and where a lightly laid finger feels the soft tissue of the brain beating under the hair and skull. At birth the actual bones are all there, but, particularly in the skull, they have not reached their adult shape and so that is altered slightly during growth in addition to the increase in size and hardness. As the baby grows the bone cells in the skull multiply and new ones slip in between the ones already there until the bones of the skull join right across when the child is nearly two years old.

When a child is seven years old, the eye sockets are as big as they will be when adult, but the skull sutures are still strongly marked and deeply toothed and interlocking. After about thirty or forty years of age the sutures become more and more smoothed over and less conspicuous. When quite old there are slight changes in the shape of the skull owing to local alteration in the bones. A certain amount of change and growth therefore takes place even in such fixed and hardened tissue as the bones of mature people. Individual cells within many tissues continue to grow long after the body as a whole is adult and has reached its full size.

In most respects we are adult or mature about twenty-five and growth often apparently stops before then. It

must not, however, be imagined that the cells of the adult human body do no more growing. That is not so, and although some cells are permanent and appear to remain so more or less for life, most of the tissues in the body contain cells which wear out and are replaced by growth through the karyokinetic division of other cells of their kind to make the equivalent amount of tissue. Even until old age is well set in there are scattered here and there where necessary, cells going through the process of karyokinetic division to replace worn out cells in whichever tissue they may be required. But in general after people are grown-up the balance is more or less regularly retained, and the food which is eaten should be properly calculated just to supply the necessary repair material for the use of the cells and for the growth of the replenishing cells. If more food is taken than is necessary, then accumulation of fat and unnecessary tissue, sometimes the growth of quite abnormally large livers or sagging muscles round the body, represent not only needless but harmful growth on the part of the cells. Further than that there may be dangerous growths in which cells have been unbalanced by some rebels in the body or by some invading dangerous germs.

In this chapter on growth, as in the other chapters, we see how all the life processes are linked together, and how growth of the whole body depends on the growth of the individual cells. That growth depends on the nourishment and on the circulating blood supplied to each cell by remote and far distant organs.

How far also the stimulus to grow depends on messages

sent from organs in another part of the body we do not yet know completely, but we do know that the growth of quite a number of structures or outer appendages depends on messages carried, we think, in the blood stream, from far distant organs. For instance, the strong hair which develops on the chest of a growing young man is encouraged to grow, and is in fact dependent on some very subtle secretions sent in very small quantities through the blood stream from his manhood's organs of sex. Similarly the soft voice of a girl (that is to say that arrangement and growth of the cells in her throat and larynx) to a certain extent is controlled by corresponding minute quantities of secretion sent as messengers from her sex organs, and thus controlling to a certain extent her body's general growth.

# CHAPTER XI.

*The Body and its Relation to the Outer World: Its Covering the Skin.*

THE skin is a seamless complete covering for the whole body, concealing the strands of muscle below it, giving the surface a uniform smooth appearance. At the same time, although but few indications of its activity are visible to the naked eye in the ordinary way, it is a very highly complicated covering, and is incessantly performing a number of different acts of service to the complex communities within.

The outer skin may be traced as a complete whole starting at the edges of the lips, joining on to the epithelium lining of the nostrils and inner lining of the ears, going over the whole skull, and down the length and all over the body. It varies a little in colour and texture in different parts of the body. In some places it is smoother and in others slightly more crinkled.

Although it is nearly uniform and simple to the naked eye, the skin is pierced by very many (a number running into millions) minute holes, smaller than the size of an ordinary pin prick. These holes are of more than one kind, some being the pores of minute sweat glands, others of the sebaceous or greasy glands, others the holes made by the hairs which lies thickly in some parts and thinly in others. Thus the skin is perforated all over the

body. These minute perforations of the body's covering are all very important in various ways, but their openings are so minute and so well guarded that they do not interfere with the protective functions of the skin.

The skin has the following main duties to perform :—

It protects the whole body. It partly clothes the body with the warmth of the small hairs which are widespread, and with local growths of stronger hairs which, as on a man's chest and on the head are in parts very thick and warm.

It provides the most primitive and most useful tools for man in the nails.

It acts as a regulator of the heat of the entire body, which we have already considered, *ante* Chapter IX.

It is continually acting as an organ of excretion.

To a certain small degree it acts as an organ of respiration.

In a very important degree it serves the central control in many directions through providing local receivers for the sense of touch.

To some extent it acts as an organ of absorption, and is able to take in, in particular, greasy substances, so that the rubbing of greasy lotions or ointments on the skin may introduce healing medicaments. Sometimes where there is extreme starvation and delicacy, the skin is used to absorb nourishing substances like cod liver oil.

Before we begin to consider how the skin with its apparent surface simplicity can perform so many important functions we must glance at its structure. This is, of

course, complicated, but is simpler than one would perhaps imagine from the number of duties that it performs.

By looking at the skin something of its structure can be seen with quite a low power magnifying glass or even with the naked eye by those with keen sight, particularly on the plams of the hands and the finger tips. The skin is finely ribbed and superficially most people's finger tips are very similar. But the fine ribs or ridges on our finger tips are so individually characteristic of every living man and woman that they form a perfect clue to their personal identity. Along these ridges the minute pores can be seen as little round specks or perforations. Although these are less visible in some parts of the body than in others, pores are to be found in most regions of the skin.

The skin consists of many layers of cells. Each of these individual cells leads a comparatively short life and when they come to the end of it, they do not become absorbed and disintegrated and carried away into the excretory system as do worn-out tissue cells from the inner parts of the body, but they flatten out and dry up, becoming flatter and increasingly horny as they squeeze against each other owing to the pressure of the living active dermis cells beneath them, until they accumulate and form a layer of tile-like cells from which gradually all the details of the cell structure disappears. At the very outside of the skin (the part in contact with the world and which we see as the skin surface, *a*, fig. 29) which is continually being renewed and replaced from below, *b*, fig. 29, to make good the loss due to friction and outer contact, we have these thin flattened cells which

are called the "epidermis." The final stage of these cells one can easily see on the inner sides of black woollen stockings, as flecks (looking like a very fine white powder or chaff which have come away from the skin. Also if through illness or from any other reason, the skin has not been bathed or rubbed for a week or so, a hot bath and the friction of a rough towel will bring off rolls and flakes of these flattened cells from the skin, together with greasy secretions and dirt.

**The arrangement of arteries, veins and nerves in the skin.**

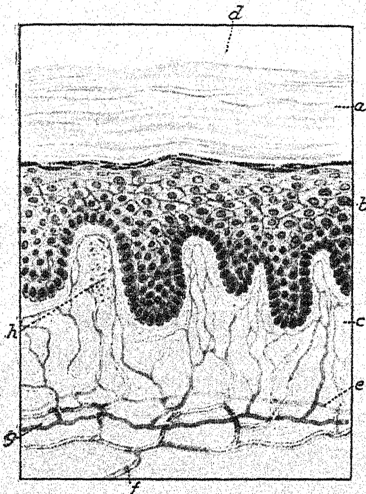



FIG. 29.

*a* *Outer layer of epidermis*
*b* *Lower layer of epidermis*
*c* *Corium or active portion of the skin*
*d* *Outer air*
*e* *Nerve*
*f* *Vein*
*g* *Artery*
*h* *Special end organ of nerve*

These outer cells which the body has finished with form a layer, which for the protection of the living ones beneath is water-proof. By the very fact of their being so regularly destroyed as individuals, together they make a layer which is, as a whole, indestructible. A minute prick or a little scrape merely takes off more rapidly than usual a rather deeper layer of these cells, which the body arranges to be able to afford to spare. They contain no blood vessels, and thus if you take a razor and peel off

the very thin outer surface of the finger or any part of the skin, it will not bleed. And you will cut merely the outer layer of these hardened epidermal cells.

**Base of a hair and sweat glands in the skin.**

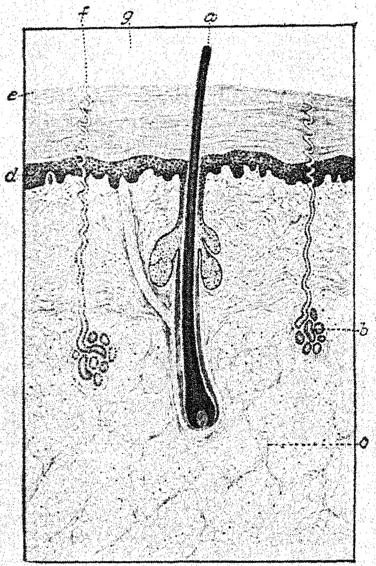



Fig. 30.

*a Base of external part of hair*
*b Coiled sweat gland cut across*
*c Connective tissue*
*d Lower layer of epidermis*
*e Outer layer of skin*
*f Opening of sweat duct*
*g Outer air*

The active life of the skin with all its manifold activities takes place in the *dermis* underneath. There lie the bulbs or roots of the hairs, there are the coiled active ends of the glands, and there too are the blood vessels and the nerves which all actively assist in performing the many functions that are characteristic of the skin. For the details of those layers see figs. 29 and 30.

When one skins an animal, therefore, one is not taking off a single solid sheet of material like a sheet of wrapping, although it comes away as though it were all one uniform layer, but one is peeling off a covering composed of very many different types of cells.

The *protection* afforded by the skin, as we have seen is partly supplied by its power continually to give off

portions of itself when in contact with the rough outer world, and these portions being composed of old tissue cells are no loss to the body. Where the wear and tear is greatest, particularly for instance the soles of the feet and the palms of the hand, the layer of old cells is thickest. One can see this for instance when a blister forms on the sole of the foot. What a thick tough layer of skin comes off with it without any bleeding or any serious injury arising beneath it!

Sometimes the skin gets too active in giving rise to old cells and bits of old, hard, callousy skin form centres we call corns. These grow at points where there is particular pressure, caused, for example by badly fitting boots, or the constant use of a tool such as the knife of a linoleum layer or cobbler. In tender skins they may be simply due to the unnatural covering and pressure of shoes and stockings, or to insufficient baths. In a natural bare-footed existence the skin on the soles of the feet is very thick and protective, but it does not give rise to the hard corns and callosities from which modern men and women so often suffer.

The skin is also protected by being oiled from within so that there is a fine grease film all over it. This form of oil is supplied by the sebaceous glands, which, as you will see in the diagram, fig. 30, *b*, consist of active groups of cells excreting greasy substances, which exude through the small tubules leading to the surface. Many hot baths tend to wash away this greasy film too much, and then it is wise to do as the Ancient Greeks did, and so many savages still do, rub oil or grease on our bodies. But

a dry skin is fashionable just now, and on the face at any rate a film of grease is, although desired by nature, not likely to be popular. The natural fine greasy film, however, should be barely visible, and the very greasy surface which is characteristic of people who are not in perfect health, is due to an excessive production of an acid grease which is sometimes due to wrong forms of living and eating, and also may be due to the extra work thrown on the skin when the kidneys have over-much to do or are not doing their work properly. The skin and the kidneys share the work of excretion to a certain extent, and if either is not working properly the other is overworked.

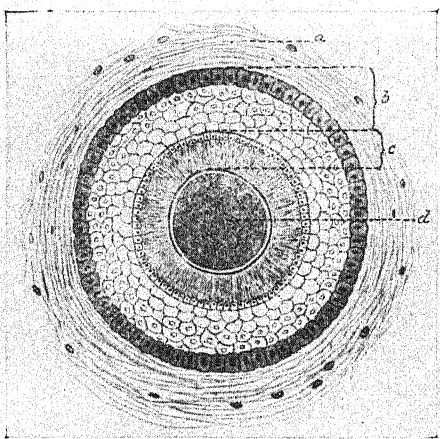
Whenever the skin is magnified, the hairs become conspicuous in it. There are several distinct kinds of hairs, the most universal being the fine, almost invisible, light coloured, short hairs, of which there are large numbers all over the body. These are the remnants of the fur with which our ancestors were probably covered.

Then there are the special, long hairs on the head which are so thick as to be really a protective covering and keep the skull warm in winter, and shield it from the intense rays of the sun in summer. There are also other thick hairs in different parts of the body of adults, and also the specialised hairs round the edges of the eyes. The eyelashes on the lids are there to keep dust and sweat and other things from going into the delicate eyes. Similarly the hairs inside the nostrils keep coarse granules of soot and dust from penetrating the breathing passages.

A single hair although smooth and simple to the naked eye is actually a complicated and interesting structure

growing from the lower dermal region of the skin. There is a bulb-like base to the hair deeply embedded in the living parts of the skin or dermis (see fig. 30). There being richly supplied with blood vessels and food it gives rise to a number of specialised cells, which, like the cells of the outer epidermis, tend to lose their soft active protoplasm

**Drawing of a single hair cut across and very much magnified to show the various layers of cells as seen under the microscope.**




*a Fibrous sheath*
*b Outer root sheath*
*c Inner root sheath*
*d Section of hair*

FIG. 31.

and nucleus and to become flattened and hardened. The cells composing the hair by their flattening and overlapping (like minute tiles round each other) together create the hard smooth gloss of the hair itself. The way the cells are arranged when the hair is cut across is seen in fig. 31.

Each hair generally has one or two or even more greasy or sebaceous glands associated with it, which pour their excretion of grease around the hair column and keep it moist and well supplied with natural food. Near the base of the bulb too runs a muscle which when stimulated by its appropriate nerve can make the hair stand up on end or erect itself to a certain extent. This nerve is stimulated by changes of temperature and then tends to pull the papillæ at the base of the hair. The common experience of being covered with "goose flesh" when taking off clothes for a cold bath, or when suddenly going out into the cold is an illustration of the working of the muscles at the base of the small hairs covering the body. Their contraction forces up the little papillæ of skin. When the body becomes acclimatised or accustomed to the temperature they relax and the surface smooths out again. Fear can also affect the muscles in the skin, and the old saying "the hair stood up on end with fright" has some basis of truth in it. You can see hair standing up either with fright or rage when a cat's back bristles at a dog. This does not often happen in human beings, although it may take place in extreme anger or fear.

The useful *tools* provided by the skin are the nails both on the toes and on the fingers, which when left untrimmed grow long and hard, and to some extent resemble the claws of animals. Even when cut and cared for the nails are very useful, and are, in fact, the only actual tools with which nature provides us. In some ways their structure is like that of hairs, only instead of forming circular separate groups of cells, the flattening process

goes on in a definite zone or groove, giving rise to the oval plate like substance of the nail, which continually growing up from the base is worn away from the active or free end at the tip of the fingers. The cells in the nails as in the hairs have no longer any blood vessels or feeling in them and are flattened and almost dead cells continually being pushed upwards and outwards by the growth from the living cells beneath.

The excretion which goes on through the skin has already been mentioned in another chapter (" Warmth and Sleep " pages 91, 92) and is principally seen in the form of perspiration which is continually passing off through the fine canals leading to the pores on the surface of the skin. The loss of the invisible perspiration which is coming off from the skin continuously is a very necessary and important part of our bodily functions, and hence when the pores of the skin are blocked, as they are by dirt or by painting the body, the health of the whole is affected. About a pint of moisture a day should pass off invisibly from the skin, carrying with it waste products from the surrounding tissues and thus lightening the work of the kidneys. In addition to this invisible perspiration, when the temperature is very high and the body is thus too warm, and when active work or exercise is being undertaken, perspiration comes off too quickly to evaporate invisibly into the air and collects in drops over the skin. The perspiration in a healthy, active man should be alkaline, or not very acid, but where the kidneys are not working properly or the man is not in perfect natural health, quite a considerable amount of uric acid comes

away with the perspiration. This increases the acid in the perspiration, and while it relieves the whole system it sometimes gives rise to local irritation. For this reason, Turkish baths are good for those who have rheumatism and other diseases as they clear away the impurities in the system that are tending to poison the tissue cells.

*Respiration* or breathing through the skin takes place only in a very minute degree. This appears in a way a rather curious thing because it would seem that it should have been so easy to breathe in and out through the pores of the skin as they are all exposed to the air. However, breathing actually takes place almost entirely through the lungs, although it is supposed that there may be limited exchange of oxygen and carbonic acid gas through the skin.

Finally one of the most useful functions of the skin for us in our highly complex lives is the *sense of touch* contained in it. On the sense of touch depend almost all the delicate and complicated things we do, and hence without our skin sense of touch, civilisation would never have been able to advance. This will be considered more in detail when dealing with the various senses (see Chapter XII, page 125).

The skin also may almost be said to have a special *temperature sense*, as distinct from touch in its simplest form and it is able to distinguish between hot and cold, and to react to both heat and cold in such a way as to protect and control the other functions in the skin on behalf of the rest of the body.

The differences in the colour of the skin vary according to the times of day, the state of health and the different parts of the body, the skin on the cheeks tending to be much rosier and pinker in colour than for instance that on the back of the neck. The colour chiefly depends on the transparency of the outer layers of the skin, and the amount of blood which is circulating in the capillaries (see fig. 29) of the living part or dermis immediately below. Although no human being can control it entirely at will, colour is partly controlled by the nerves, and therefore by the emotions. Thus when the skin flushes red all over the neck and face, as in blushing, it is due to the sudden increase of blood in the capillaries, which is caused by a stimulus to the nerves by something said or done to affect the central consciousness.

Another curious thing about the skin is that though it may be bathed in light it cannot perceive it, sight being localised in a central pair of organs, the eyes. Yet the skin absorbs light and transmits the rays to the tissue cells beneath, some light rays penetrate the skin and thus affect the whole system very fundamentally such, for instance, as the ultra violet rays in sunlight.

Human beings are never so well and never so happy as when their skins are exposed freely to the air and the sun, and the sense of exhiliration and health which comes from sun and sea bathing is almost entirely due to ready evaporation, and the glow of light rays which penetrate the skin, and through it tone up and stimulate the whole system.

Human beings like animals were intended to live in

direct contact with sun and air, and those who are fortunate enough to be able to give their skins these luxuries (which alas have become luxuries although once the common right of all) maintain themselves in much better health and in much greater physiological happiness than those who over-clothe their bodies and who keep them stuffy and constantly below par.

This, always known to "nature lovers," has recently been recognised by medical experts, and there is now some hope of civilised man once more giving his skin the luxuries and health to be found in light and air, which the untutored savage secures without difficulty.

## CHAPTER XII.

*The Body and its Relation to the Outer World: The Senses:—Touch.*

TOUCH is our most extensive sense. Almost every part of the body when touched externally feels with a great degree of accuracy the nature of the contact, so that we know whether something very soft and warm, or something cold and sharp, hard or smooth has touched us.

The power to perceive the nature of anything touching us differs in intensity in different areas of the body, and anyone with a mind for a simple experiment can test this amusingly and interestingly for himself with a pair of blunt-pointed measuring compasses. If the points of these compasses be placed close together (say one-tenth of an inch apart) and the eyes are closed, the tips of the fingers will feel the two distinct and separate points when touched by them, and so will the tip of the tongue, but the back of the hand will feel as though there is only one point of contact and so will the back and shoulders. Indeed if the points of the compass are placed quite far apart (one or two inches) there are many regions on the back and loins where the two points would not be felt as two separate and distinct touches, but it would seem as though they were one, while on the fingers, of course, and even the back of the hand, the points of the compass

a fraction of an inch apart would be instantly recognised as two independent points of contact. The power to feel such contact, that is to say the sense of touch, depends on the nerve endings lying in the living part of the skin or dermis, see *h* in fig. 32.

**Touch: The nerves and nerve-endings in the skin.**

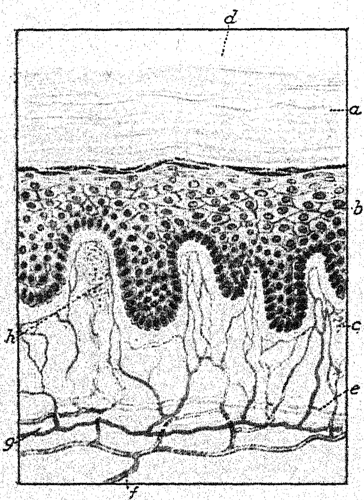



FIG. 32.
*For description see page* 115

The degree of swiftness and sensitiveness in perceiving very delicate touches, and judging the distance of two simultaneous points of contact and all such refinements of the sense of touch vary in different regions of the body because of the varying number and development of the nerve endings and their surrounding cells in the different regions of the skin. In some sensitive parts of the skin, such as in the fingers and the tongue, there are very many well-developed, specialised nerve endings of various sorts, and also a large number of very fine ramifications of the nerves running up to the base of the epidermis. Hence at any point of contact, the pressure is almost certain to be transmitted to a nerve ending very close by or immediately under the point of contact, while on the loins or back where the nerve endings are far less frequent, one of

the points may touch a spot rather far from a nerve ending and thus the mechanism there is not so delicately adjusted to record the nature of the contact.

Although the sense of touch like all our other senses, depends on nerves which convey the stimulus to the reasoning brain, yet the nerves by themselves do not carry—indeed cannot carry—a correct message if they are approached direct. Touch on a nerve itself merely registers pain. But the nerve ending when surrounded by its associated protective cells in the dermis will initiate a correct sense of touch, registering back to the reasoning brain, softness, hardness, heat and texture. If the protective and associated cells are removed and the nerve itself is touched anywhere, it is not able to register any of these sensations correctly because it *suffers*. Hence although nerves are a vital part of the sense organs, they cannot directly carry the right sensation, and if roughly handled, or if pressed upon too heavily or touched too suddenly will convey pain instead of the correct complex sensations of touch. A touch on a specialised sense organ, such as the eye, will convey a totally different impression from that it is organised for, so that a blow or a swift light touch on the eye ball, even through the lids if the eyes are shut, is translated by the nerves into a sense of light and pain combined and does not give any idea of the true nature of the contact or the object causing the touch.

The slender elongated nerves themselves do not perceive the touch, but they only carry the messages; it is the nerve endings which are specialised to receive the touch sensations.

The way the nerves ramify in the living cells of the skin, and how their ends are enlarged to form little capsule-like, specialised endings or papillæ is seen in the diagram, fig. 32, page 126.

The different feelings of heat and cold when hot and cold objects come in contact with the skin are also forms of touch sensations. Although we do not yet know all that should be known about nerve endings in the skin, it appears that some of the nerve endings are specialised to perceive heat and some to perceive cold, and psychologists have plotted out maps and diagrams of the various regions of the body showing what are called "heat spots" and what are called "cold spots," that is to say which parts of the body feel heat and which parts of the body feel cold. At the same time we must not forget that what we call "heat" and what we call "cold" are not distinct things, but merely degrees of the same thing and therefore relative to each other, so that in my opinion, much stress must not be laid on this rather crude idea of heat and cold "spots."

It is easy to test how heat and cold merge into one another if you take three basins, one filled with water as hot as it is safe for the skin to touch, one with water the chill off or luke warm, and the other with ice-cold water. Keep one hand in the hot and the other in the cold for a few seconds, and then put them both in the basin containing the luke-warm water. To the hand that has been in the ice-cold water it will feel hot and to the hand that has been in the hot water it will feel cold. Hence we see that recognition of the heat or cold of the

water is merely a relative sensation, measurable in terms of comparison what the hand has been enduring before coming into contact with it.

Another form of touch is the *sense of pressure and weight* which are realised and used so frequently in our ordinary life. If a very heavy weight is placed upon us we experience quite a different feeling from the ordinary feeling of touch, because the body being a soft and sensitive organism, the heavy weight crushes the blood vessels, and therefore hinders locally the circulation of the blood and upsets the life of every cell suffering from the pressure. But when we voluntarily lift a heavy weight we feel the *pressure* of that weight. The sense which perceives this must be a combination of the definite nerve endings of simple touch with some messengers conveyed from the muscles doing the muscular work involved in lifting the weight. Exactly how these are transmitted, indeed what their nature is, science is not yet prepared to say in simple terms. The instinctive actions on the part of our tissues are so marvellously interlocked in their perceptions and reactions, and recognise external conditions swiftly and effectively, but often in a manner which we, with all our study, are unable to explain.

Considered scientifically, *all our sense organs are refined forms of touch*, the specialised cells of the eye being specially sensitive to the delicate contact of the waves of light, and our sense of smell being due to cells specially sensitive to the wave lengths of various aromas, as our hearing is to wave lengths in the air.

In every day language, however, we do not talk of such

subtle, ultra-forms of touch as "touch," but confine the word to the well-known sense we experience every time our skin comes in contact with any material body in the outer world. A little thought will show you that almost every process which makes for our civilisation depends on touch in some direct or indirect form.

## CHAPTER XIII.

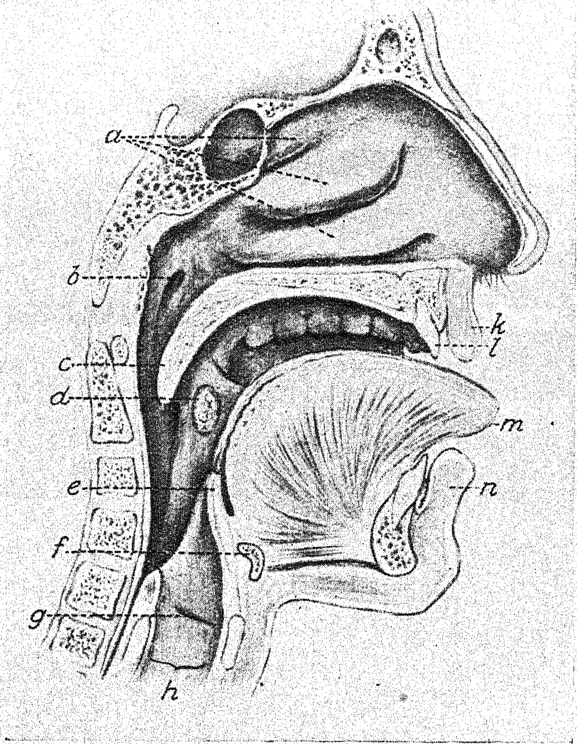
*The Body and its Relation to the Outer World: The Senses: Taste and Smell.*

THE two senses of taste and smell, although they are supplied by different nerves and each has its own distinct structure, are nevertheless, more nearly overlapping than any other pair of senses in the economy of an ordinary human being. For instance a good deal of the sensation which the ordinary person attributes to taste is really smell, and the two senses combined are responsible not only for the enjoyment of our food (which is of great physiological value in assisting digestion) but also in protecting the eater from bad, unsuitable and poisoned food.

In both the sense of smell and in the sense of taste, the sensation is conveyed to the conscious brain through special nerves, and each is stimulated and caused to feel and carry the message by the impact of minute particles. These particles, to be perceived either as a taste or an odour, must be associated with a liquid in such a way as to be dissolved. Juicy food thus contributes directly the liquid which re-acts, and when dry substances give off an odour or a flavour, the minute invisible particles from them are dissolved in the moisture on the surface of the living cells which form the receiving apparatus in the

nostrils or on the tongue. Hence both in taste and smell the cells of the receiving apparatus are bombarded by

**The nose, mouth and tongue cut through to show the internal cavities and their relation to the throat.**




*a Turbinals*
*b Orifice of auditory tube*
*c Uvula*
*d Left tonsil*
*e Epiglottis*
*f Hyoid bone*
*g Left vocal cord*
*h Cavity of throat*
*k Upper lip*
*l Tooth*
*m Tongue*
*n Lower lip*

FIG. 33.

microscopic molecules in solution. Both taste and smell, therefore, are in this microscopic way specialised senses

of touch, but the touch is of so refined and subtle a nature as to depend on the chemical molecules concerned.

*The Sense of Smell* is concentrated in the upper regions of the nose. The upper cavities of the nose are lined with specialised epithelium and well supplied with the olfactory or nerves of smell which come through the perforated bone partition at the top of the nose direct from the brain itself. Seen as though it were cut through vertically, the nose passages are shown in the diagram, fig. 33, page 132.

The cells lining the skin or epithelium of the nose are very thin walled, tall and narrow, all standing edge to edge. Fine nerve endings ramify among them, each ending in a minute process. In the film of liquid on the surface of this epithelium, the minute invisible particles coming off from anything which has an odour, bombard these sensitive cells, and the nerves carry the message from them to the brain. How minute is the quantity necessary to be perceived by these cells can be imagined from the fact that many substances which have faint odours, such as amber which has been breathed upon, sandal-wood and other solids remain apparently without alteration for centuries, yet all the time they are giving off minute particles into the atmosphere in a sufficient quantity for them to affect the cells in the nostrils of anyone who is within reach without, apparently, causing any alteration whatever in the original substance. On the other hand some odours very quickly evaporate and distribute themselves into the air, and, therefore, soon get lost because they are so much diluted. Thus many flowers, which have a strong sweet scent when the buds

are fresh and first open give off odours which evaporate away and leave the old flower almost scentless.

As our nostrils are able to perceive the subtleties of such delicate and minute molecular quantities of substances as those mentioned above, it is no wonder that the thick smells of cooked food affect them powerfully, nor that other substances which are giving off a rapid bombardment of molecules may cause an overpowering or unpleasant smell.

Unpleasant odours may arise from substances which have a chemical effect on cell life, such as some subtle poisons which absorb water so rapidly that the effect causes a stinging or prickling sensation in the epithelium cells. Arising from such substances we are not dealing with the simple sense of smell, but with what seems like a sense of smell, but is really a combination of that and of chemical effects deleterious to cell-life. On the other hand we may experience the sense of smell from substances, which, although very minute in quantity and very subtle in their action, may be absorbed so as to poison the whole system without giving rise to more than a faint sensation in the olfactory nerves. Among such odours are several of the bad "gases from drains," and a very poisonous and dangerous gas, carbon monoxide, which has a faintly sweet but almost imperceptible odour, and yet a few whiffs of it mixed with air may be enough to render senseless or even to kill a human being.

The sense of smell as an index to the strength or importance of chemical reactions going on in the body is one of the most difficult and mysterious things to explain,

partly because we have no properly graded vocabulary for the different types of smells, and hence find it very difficult to talk about them and discuss them. Moreover a sensitive sense of smell is becoming increasingly rare amongst so-called civilised human beings. Animals like dogs, and also unspoilt savages, have a much more acute sense of smell than is usual in modern communities. The Japanese alone, I think, amongst civilised nations, encourage and train the sense of smell by delicate games of skill. The guessing of different kinds of faint odours are among their national pastimes.

In cities where the air is poisoned by the virulent gases coming from the exhaust valves of motor-cars, the sense of smell is tending to be destroyed in the most dangerous manner, so that people are able to tolerate without smelling the badness of these odours, though they are thoroughly unwholesome for the whole system. Motor-contaminated air is particularly bad for little children who walk in the streets with their noses almost on the level of exhaust pipes of motor-cars so that their sense of smell becomes dulled or destroyed, and they lose what should be a great safeguard for them all through their lives, as well as an acute pleasure were they to live as nature intended, surrounded by the sweet scents of earth and plants.

*The Sense of Taste* is not quite so local as the sense of smell. It is found chiefly on the tongue and the back of the palate although a certain power of taste is traceable to some isolated papillæ on the back part of the throat.

The tongue is the principal organ of taste, and as everyone knows the tongue has a very soft moist surface, slightly rough with the roughness of plush, that is to say a roughness depending on the massing together of fine processes which stick out over the surface of the tongue. In some animals this roughness is rasping, and the front part of the tongue has such strong papillæ that it is used to lick the meat off bones, and feels very rough and cleansing when applied to the surface of the human finger. In human beings, however, the papillæ on the tongue are not so long, nor so strong, but are very numerous. Of them the three most important kinds are: the fine pointed papillæ all over the tongue, which are chiefly useful for their sense of touch, the taste papillæ which are found down the sides of the tongue, and are somewhat mushroom-like in shape, in which there are nerve cells and specialised taste-buds, able to convey the sense of taste to the brain. In the "V" like ridge at the back of the tongue are a number of mounds or *circumvallate papillæ*, on which taste buds are found (see fig. 34). Taste buds are groups of spindle shaped cells, ranged together like the closed segments of a bud, and these lie close to the nerve endings in such a manner that their fine points are in contact with the fluid in which the tasty substance bombards them. The nerve running to their base is then stimulated and conveys the sense of taste to the brain.

How confused the two senses of smell and taste may be is demonstrated when a severe cold in the head seems "to take all the taste out of one's food." As a matter of

fact the cold does not much affect the taste of the food, but chiefly interferes with our power to smell the odours rising from the masticating mass of food which come up the back passage of the nostrils and are smelt by the olfactory nerves. If the food is delicious, and the sufferer from a bad cold desires to "taste" it, he can do so if he blows his nose while the food is in his mouth and then draws a quick current of air up the back of the nostrils. He then really smells but thinks that he can taste the food for a moment before the olfactory cells are again clogged up with the mucus which collects over them as a result of the cold.

**Tongue and Papillae.**

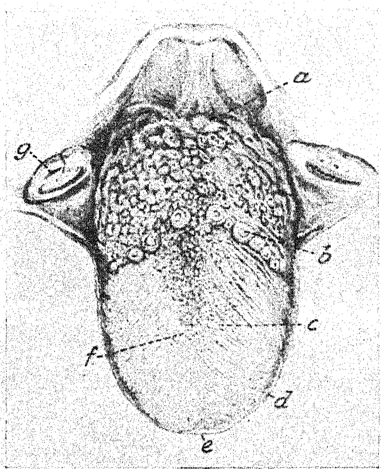



FIG. 34.

*a Root of tongue*
*b Vallate papillæ*
*c Fungiform papillæ*
*d Margin of tongue*
*e Tip of tongue*
*f Conical papillæ*
*g Tonsils*

In the unnatural life of cities, the sense of smell and taste are both too little used except in connection with food, and as unpleasant odours are so often characteristic of the streets, perhaps to have these senses somewhat deadened may have its compensations, although it may be dangerous. But to the dweller in the country the

numerous odours of the earth and flowers at different times of the day and night are a continuous source of enjoyment which can be cultivated. It is probably known to few how well-nigh universal pleasant odours are in natural objects, nor how rich and varied may be the sensations they afford. Even such a hard and ancient stone as flint, if freshly broken open and breathed upon, has a very characteristic odour, although not one person in ten thousand can perceive it.

## CHAPTER XIV.

*The Body and its Relation to the Outer World: The Senses: Hearing and Balance.*

THE sense of hearing depends upon the air, and that quality in the air which causes it, when disturbed, to transmit ripples or waves much like those in the sea. All sounds are due to disturbances of one sort or another which start large or small, swift or slow, waves in the air much as a stone starts a series of ripples when dropped into the water of a still pond.

The recent extension of wireless transmission has made everyone realise that we may dwell in the midst of sounds which we cannot hear, and definite waves are transmitted through the air for very long distances, of which we should know nothing if it were not for the apparatus of wireless receivers. When the necessary apparatus is put together then we hear the sounds, and thus can even recognise personal qualities in the human voice transmitted for many miles in a way which would have appeared like magic to our great grand-parents.

Similarly with regard to local sounds which may be made quite close to us. Some jars and vibrations started in the air give rise to waves so swift and so small that the receiving apparatus in human heads is not sensitive enough to receive them. Then there are other sounds, like the shrill cry of a bat, which the ears of some people can hear

quite clearly, but which others who are not in the least deaf yet can not hear at all.

Hearing depends on two very special and very complicated pieces of apparatus within the head protected by the skull, but of which the outer receiving portions are visible—our well-known ears. Our ears have somewhat shell-like, convoluted, cartilaginous flaps on the outside, which tend to catch the sounds and perhaps amplify them to some extent, and send them into the canal which carries them to the membrane or tympanum where outer contact ceases. Animals have long pointed ears which they can move at will in order to catch sounds, but very few human beings retain the muscles which make it possible for them to wag their ears, although a few can do so.

**Drawing to show the outer, middle and inner ear.**

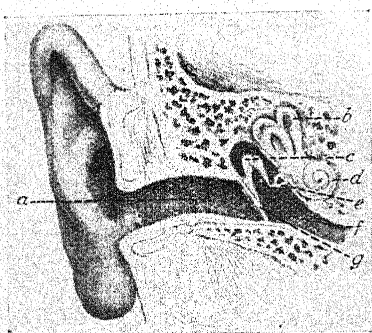



FIG. 35.

*a* *Canal of outer ear*
*b* *Semicircular canal*
*c* *Malleus*
*d* *Cochlea*
*e* *Stapes*
*f* *Tympanum or middle ear*
*g* *Tympanic membrane*

In each ear, when the sound waves have been received and have travelled so far as the tympanum membrane (see diagram fig. 35, *g*) they cause it to vibrate, much in the same way that a drum vibrates when struck lightly. This membrane closes the communication with

the outer world, and the sound waves are, after that transmitted through very complicated curved canals filled with a liquid like lymph—a special lymph found only in the ear canals—and also through three small interlocking bones called the ossicles. There are within the ear two other membranes and what are called semi-circular canals, which are complicated sac-like, twisted structures, so that the whole apparatus looks rather like a twisted snail (see fig. 36). The semi-circular canals and other parts of the internal ear are lined with a special membrane of epithelium cells, mingled with which are thin pointed hair-like cells in contact with the lymph-like fluid, and among which are some very small hard crystals, which are comparable with those found in the balancing sacs of lower animals and which are called otoliths.

**Diagram of the canals and nerves of the inner ear.**

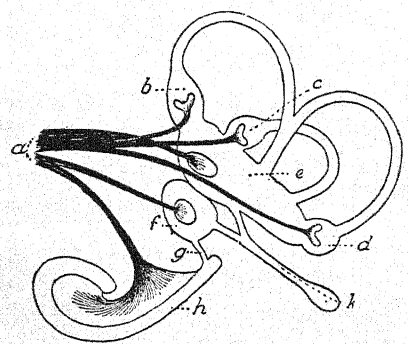



FIG. 36.

*a Auditory nerve*
*b c d The dilated end of the three semi-circular canals*
*e Utricle*
*f Saccule*
*g Canal joining cochlea to saccule*
*h Cochlea*
*k The commanding tube between the utricle and saccule*

It is possible that these otoliths play an important part in helping us to appreciate our balance, because it is thought that largely through the feelings in our ears

that we recognise whether we are standing upright or are bent on one side or another.

If this were so, then the hearing and the sense of balance should be treated as quite different senses. It might very well be argued that balance should be reckoned as a sixth sense, and we should not continue to speak of the old-fashioned five. We know very little indeed about the mechanism of the sense of balance.

As we mentioned when dealing with the comparatively simple structure of the nerve endings in the skin, the nerves themselves do not obtain their sensations direct, and similarly the nerve endings of the auditory nerves only convey impressions received by the sense cells. The nerves of hearing branch in a complicated manner and connect themselves with the twisted labyrinth and curved canals of the inner ear, their finest fibres ending among the bases of the hair-like processes amid the epithelium cells lining these structures which convey to the nerve-endings the sensations which the nerves carry to the brain, and which we interpret as hearing. Just as a tuning fork vibrates in response to vibrations of a similar sort near to it, so the many thousands of hair-like cells which line parts of the inner ear are set quivering by the vibrations transmitted through the outer membrane, the bones and other parts of the ear. These cells respond much in the same way as a tuning fork responds, and the result of their response is what is conveyed to the central receiving apparatus, the conscious brain.

Although the outer ear is closed by the very important tympanum or ear drum, the air pressure within and with-

out it is equalised by access to the air from the inner side, where there is a connection between the inner ear and the outer world through a canal leading to the eustachian tube at the back of the throat and nasal passages. When this tube is blocked, (as it sometimes is as a result of a heavy cold), it tends to affect the power of hearing, showing that the sound vibrations must have full play, both within and without the ear canals.

Hearing depends for its perfect reception on the simultaneous use of the two ears. This assists us in the general recognition of our relation to the outside world, for when both ears are working perfectly we are able swiftly to judge the direction from which a sound reaches us. On the other hand, many people have one deaf ear, owing to the piercing of an ear drum or to other injuries to the very delicate and complicated apparatus of hearing. The person who has one deaf ear can hear a conversation perfectly if the sounds are directed towards the ear which is in good working order, but that person is much handicapped when in the open air by being slow to judge the direction from which a sound travels. In daily life, it is, of course, often important to know at once, without having to turn round, from which direction a sound of danger is approaching. We may want for instance to spring on one side and avoid a travelling object, such as a motor car, which may be approaching rapidly. At the bend of a road, where sight could not help, a person deaf of one ear would tend to stand moving the head from side to side endeavouring to ascertain from which side the sound was travelling, and the delay might be fatal. The

*two* ears are needed to locate sounds swiftly, otherwise there appears to be no good reason why nature should have put herself to the trouble of making two such complicated and delicately balanced receivers of sound in our heads.

## CHAPTER XV.

*The Body and its Relation to the Outer World: The Senses: Sight.*

OUR power of sight depends on the specialised power of two definite sense organs, the eyes, to receive and hand on the effect of those waves in the air which we call light. Light waves move with intense rapidity and both their size and their swiftness varies, and these differences give rise to what we call colours. The existence of colour-blind people who nevertheless can see the form and shape of an object makes it easy for us to realise that the power to see colour and the power to see shapes of objects must depend on different effects upon the nerves of vision.

As we observed when considering the other senses, the actual nerves themselves are not capable directly of perceiving the sensations caused by any of the objects our senses deal with. All the variations of environment which we ultimately perceive through sight depend on special sensitive cells receiving these impressions, and conveying them to the nerves which in turn convey the effect from these cells to the brain through the main branches of the optic nerves.

The complicated groups of cells which are specialised for this purpose, and all the subsidiary assistant cells required by our organs of vision are found in two sunk

cavities in the skull. These we call the eyes sockets. In this the eyes differ from the ears, for the inner ear lies completely surrounded and protected by the bones of the skull, but the eyes are outside the skull, merely lying partly protected by their sunken rounded beds in the front of the skull. The curtains which close and protect the front part of the eyeball are merely membrane and skin as we can feel for ourselves in our own eyelids. Through a comparatively small hole or foramen in the skull at the back of each eyeball, there comes the thick branch of the main optic nerve, and it there divides into a number of nerves surrounding the eyeball, its final branches ramifying among the special perceiving cells.

The eyeball is a nearly circular, rather tense firm object. Attached to it are several strong elastic bands of muscle which hold it in its place in the pit of the eye sockets in the skull, and at the same time they are elastic enough to permit it to rotate so far as to see things from different angles as required.

The eye is a most delicate structure, and is carefully protected, so let us glance at the accessory arrangements surrounding the eyeball. In the diagram seen on page 147, fig. 37, you will see an eye with the lids open and pulled somewhat back so as to show their rims. Round the rim of each eyelid are the long strong hairs of the eye-lashes, which keep away from the eye light objects, such as flying insects, blowing grit and so on. Also, the slightest touch on their tips warns us to shut the lids and thus protect the very delicate and tender surface of the eye. As seen in the diagram, round the margins of the lids are

glands, some of these being grease glands to keep the eyelashes well lubricated. Other glands are for the protection of the eyeball. Above the outer corner of each eye lie the special lachrymal glands and their ducts, the arrangement for producing tears. Tears are continually in use even when one is not actually crying; these glands are always secreting a small quantity of tear fluid which floats across the surface of the eyeball, keeping it moist and clearing away grit or dust and thus cleansing and thoroughly lubricating it. Even in a grown man, therefore, who would scorn to "cry" the tear ducts are very important, for the eye which is dry is immediately liable to injury and soreness. It is only when sudden and excessive emotion or an injury to the eyeball forces an excess of tears to overflow that we see the tear drops which go by that name. The invisible tear fluid slowly passing over the eye, enters small canals on the inner corner of each eye, by which it passes to the nose and is

**An Eye with the lid turned back showing**

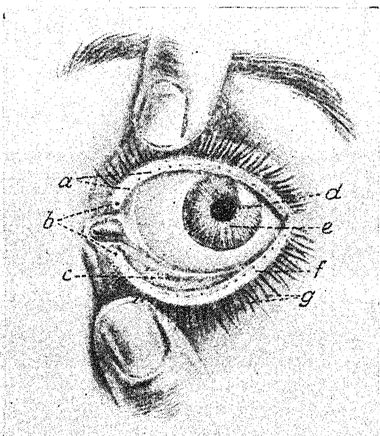



FIG. 37.

*a Opening of ducts of tarsal glands*
*b Ends of tubes leading to canals into the nose through which tears usually escape*
*c Tarsal glands*
*d Pupil*
*e Iris*
*f Eyelid*
*g Eyelashes*

there evaporated away at the back of the nose. Such a steady production of almost invisible tears forms a vital part of the daily machinery of the eye.

This power to produce tears does not develop until a baby is about four months old and that is one reason why it is so important that any baby should not have its delicate eyes exposed to dust or dirt or bright light, for they have not the protection of the slightly salt antiseptic water of the tear fluid. That is why it is so wickedly cruel to leave a baby in a perambulator with the hood over it in such a way that the glare of the sky goes straight into the baby's eyes, and then wheel it through a dusty and crowded street. Numbers of grown-ups who have to wear spectacles could trace their handicap to the ignorant cruelty on the part of mothers and nurses if only the eye-balls could talk.

**Inner structure of central part of an eye showing the radiating blood vessels.**

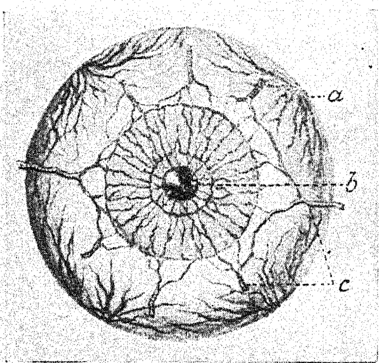



FIG. 38.

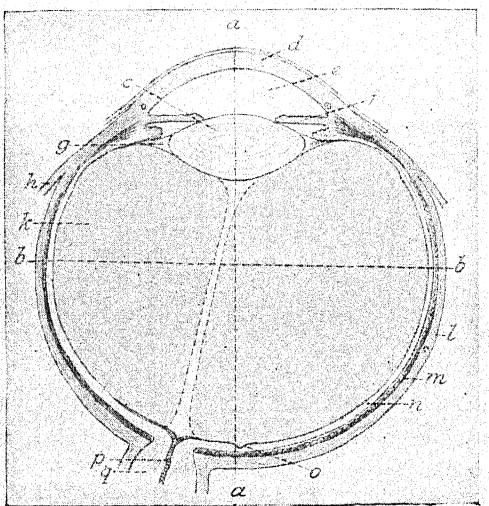
*a Veins of chorioid*
*b Aperture of pupil*
*c Long ciliary artery*

The way a human eye is built is very similar to that of several of the common animals, hence the best way of studying the structure of an eye is to get a bullock's or sheep's eye from the butcher and carefully to cut it open

and examine the different layers and the lens in it. A diagram of the leading structures will be seen in figs. 38, p. 148, and 39.

When you look into the eye as in fig. 38 you will see that within the white of the eyeball lies the central or

**An Eye, cut through at right angles, showing the parts :—**




*a* Optic axis
*b* Equator
*c* Lens
*d* Cornea
*e* Anterior chamber
*f* Iris
*g* Suspensory ligament
*h* Muscle of the orbit
*k* Vitreous body
*l* Sclera
*m* Chorioid
*n* Retina
*o* Fovea centralis
*p* Central artery of retina
*q* Optic nerve

FIG. 39.

important part of the eye ; first the outer circle which may be coloured blue or brown, hazel or grey and which depends on the presence of different pigments or lack of pigment for its colour. Within this coloured zone you can see the dark centre, which in most eyes is deep velvety-bluish-black.

The size of this central dark spot depends on the expansion and contraction of the circular muscles which increase or contract the size of the coloured zone round the eye. This is called the iris. When it is necessary to take in as much light as possible, as when trying to see something in the dusk, or when a man is looking at a very far distant scene, then the iris muscle relaxes in such a way as to make a large entrance and thus to give the appearance of a large central blue-black spot. Also sometimes in extreme anger or emotion you may see the centre of the eye expand and thus give a deep rich look to the eye. When the iris contracts in a bright light, then the central black spot is much smaller, until sometimes the central part of the eye closes down to be a very small point.

The lens which lies immediately under the iris is a clear translucent mass filled with jelly-like central substance, and the images of all we see pass through the lens as do the images which reach a photographic plate pass through a camera lens.

In an ordinary healthy eye only a few blood vessels are visible on the eyeball and none in the central part of the eye, but all the same the eye is well supplied with minute blood vessels, as you can see clearly in the diagram showing their arrangement in the back of the iris and choroid, see fig. 38, page 148.

All these parts of the eye are more or less accessory and are there to control the supply of light, to direct the line of vision, and so on, but the real business portion of the eye consists in the numbers of fine cells lying closely

packed together to form the layer called the retina (*n*, fig. 39). These cells in some degree resemble the active cells of the ear in being long and narrow and closely packed together over a surface. They are of two distinct shapes and are more or less alternately like rods and like cones, and the active layer is called the "layer of rods and cones." It is in these cells that the wave-like vibrations of light take effect. They are the sensitive receiver-cells of the apparatus of sight. It is their power of feeling the varying wave-like sensations of light which enables them to perceive the stimulus which they transmit to the nerve cells. Beneath them come several layers of living cells with nucleii, and beneath them layers of ganglia or nerve cells, which convey the sensations received by the rods and cones layer and carry them through the finer branches of the nerves to the big optic nerve, which ends at the back of the eyeball, see fig. 39 *q*, page 149. This optic nerve is the one through which the sense of sight is carried straight to the brain.

There are other nerves, however, in the eye, subsidiary nerves which control the movement of the various muscles, nerves which control the eyelashes and the supply of tears and so on.

A curious point in the process of vision and one that can easily be detected in your own eyes, but which most people would miss unless they made an effort to find it in themselves, is the existence of what is called the "blind spot." Every eye has a roundish blind spot which corresponds exactly to the base of the thick optic nerve which ends at the back of the eye. Where the trunk

of that nerve ends no sight is possible, and if you look at the simple diagram shown below, which is repeated from Huxley's wonderful classic "Lessons in Elementary Physiology," you will see a cross and a dot. If you close your left eye, and then look steadily with the right at the cross on the page, you will see both the dot and the cross quite plainly, but if you move the book slowly towards your eye, keeping it still fixed on the cross the

Fig. 40.

dot will suddenly disappear, but if you still keep the book moving slowly towards you, it will come into sight again.

This is due to the fact that the moment the dot disappears it does so because it coincides with the direction of the blind spot.

Just as we noticed when considering the sense of hearing that it is important to have the two ears in order to be able to locate sound, so in vision the value of having two eyes is not only that if an accident deprives us of one we have a second which will keep us from blindness, but that the daily use of the two eyes enables us to fix the position of objects and to estimate their distances much more accurately than we could were only one eye in use. If you shut one eye and then try with one finger to feel the distance of untested objects, you will experience a

certain fumbling in estimating their position, and realise how much more difficult it is to locate their distance swiftly than when both eyes are in use.

The way an image is formed on the retina is seen in a simplified manner in the diagram, fig. 41. The lens in our eye reverses each image we see, just as the lens in a camera reverses the image photographed on the sensitive plate at the back. The figure shows you that any object "*a–b*" throws rays of light, which passing through the lens, get deflected in such a way as to reverse

**Inversion of Images.**

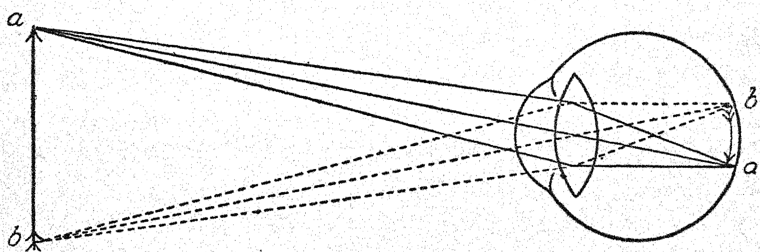



FIG. 41.

the object at the back of the retina. The image on a photographic plate, of course, remains reversed, but our conscious brain puts this right for the images which reach our retinas are interpreted to our consciousness.

How much the full effect on our sight depends on an intelligent interpretation of what is conveyed to our eyes, is plainly to be discovered on a country walk when a distant object may be taken for a shimmering lake, while it may be only a piece of glass near by or a large greenhouse further off, or we may interpret a piece of white news-

paper lying on a bank at some distance as the moving body of a child or we may imagine that a couple of hens are a pair of horses. These hens when we think of them as horses appear to our minds to have all the qualities of horses, four legs and all the prancing movements, but directly we apply a spy glass or approach closer, the likeness to horses vanishes, and we see that the objects are two-legged hens.

Sight more than any of our senses therefore is incomplete until we have learnt a good deal of the outer world, and are able to interpret by our intelligence the appearances which reach our eyes and pass through them to our brains.

# CHAPTER XVI.

## *Nerves.*

IN a community of large extent, the individuals composing it must have some means of communication other than direct personal contact, and in our modern civilised and highly complex life, we have evolved such rapid direct means of communication as the telephone and telegram conveyed by an electric stimulus travelling along finely extended wires. Quite recently we have also wireless communication, of which something comparable may be existent in our bodies. The comparison with communication through the telegraph wires, however, is, although rough, a truer analogy for comparison with the methods of communication between the various fixed communities composing the complex organism of a single body.

Throughout this book we have had frequent occasion to refer to the nerves which are found in almost every part of the body, entering, as large thick strands, into specialised organs where they divide up to the finest fibres and delicate, ultimately invisible threads which ramify among the cells in as complicated a network as do the arteries and capillaries of the blood system.

The "nerves" are specialised cells and groups of cells, parts of which are drawn out into a long elastic thread-like form and in this way are crudely comparable to the

wires of our telegraph system. Seen by the naked eye a nerve consists of a whitish thread-like mass, which if magnified and teased out finely is seen to be like the strands of a rope, ultimately composed of smaller strands of still finer fibres lying lengthwise and approximately parallel to each other.

The fine nerve fibres ramify so as to penetrate the tissues of the entire body, but the congregated masses of nerve cells which form the main trunks and centres occupy two localised regions in the body. The one centre is the thick carefully protected strand of nerve fibres and ganglia in the long hollow tunnel-like region formed within what is called the spinal column, and the other centre is the still larger oval mass of the brain, filling almost the whole cavity of the skull.

Both these important centres of nervous activity are protected by bones. Within the bones are further protections of covering, specialised cells, and within them again each separate nerve cell is protected by its own sheath of fatty material. The elongated cell extensions through which messages travel long distances are each separately packed in a coating of whitish fat, much in the way that a cable is packed in canvas and other insulating coats to protect it from contact and leakage on the way. At headquarters, both in the brain and in the central part of the spine where the main cells are fully protected, certain cells of the nervous system are without this whitish fatty coat, and there form what is called the "grey matter" of the nerves, which is supposed to be the seat of our rational thought and intelligent decisions.

A great variety of different types of cells are concerned in the building up and protecting of the whole nervous system. Those specialised for the transport of stimuli or impulses have a definite but irregular outline ramifying from their main protoplasmic mass in which lies a large central nucleus, see Chapter VI. The rather short branching ramifications of the protoplasm are called dendrones and branch out from the central protoplasmic mass of the cell. The one very much elongated process is called the axon, and is the main strand through which stimuli travel, and this enormously exceeds in length that of any ordinary cell found in the body tissues (see fig. 42). Other greatly elongated structures in the body, such as hairs and long blood vessels, are composed of large numbers of individual cells combining together to build up the elongated structure, but these long nerve fibres are processes from the simple cell which extend greatly beyond the length of normal cells. A single fine process may even be traced two or more feet as a single unit from a nerve cell.

Such a process is seen very much shortened, or otherwise it would not get into the page at all, in fig. 42, page 158.

Each nerve cell remains in position. Nerve cells do not travel about carrying messages or any material substance as do the blood cells, but through them, while they remain stationary, pass the thrills of a stimulus or the order from headquarters when external conditions vary in such a way as to create an impression on any of the outlying cells of the skin or any of the sense organs,

Nerves can either carry impressions from the sense organs in from the outer world to the brain, when they are called afferent nerves, or they take orders from the brain in the form of a stimulus

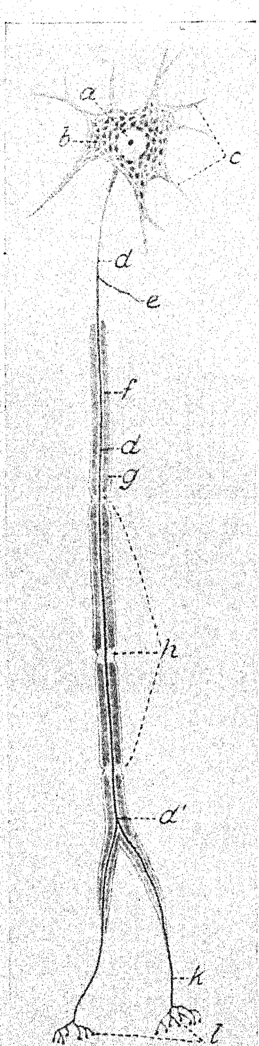



FIG. 42.

Drawing of a *single cell* from the nervous system; the whole is called a *neuron*, the main part of the cell is *a* with its nucleus from its protoplasm the processes radiate. The proportionate length of the axone from *d* to *d'* is much reduced so as to get the drawing on the page. The whole cell is magnified by 200 diameters.

*a Nucleus of cell*
*b Nerve cell*
*c Dendrites or processes for the cell*
*e Collateral branch*
*d Axon*
*f Medullary sheath covering the long extended axon*
*g Neurilemma*
*h Nodes of ranvier*
*k Naked region of axon*
*l Terminal branches*

to other organs, when they are called efferent nerves, or from the different organs within the community.

There are, therefore, four kinds of messages for the nervous

system to carry about: messages telling the central organisation what is happening in the outer world and messages in response telling the various organs, perhaps in quite remote parts of the body what to do as a result of that change in the outer world, and then also messages from the organs composing the body itself, and as a result messages of command either to the organs concerned or others in distant parts controlling and instructing them what to do.

In the active human being, a good many of the important messages and replies which control such vital functions as breathing, for instance, or walking, have become automatic to such a degree that the messages from the organs concerned do not go to the headquarters of the personal consciousness of the man or child at all, but the message is dealt with and the necessary reply sent without any record in the conscious knowledge of what is being done. That even in the growth and development of one's own life this could not always have been so is proved by watching a child learning to walk. The act of walking is a very complicated and difficult art, and it involves the control of a great many different muscles and organs which have to be balanced and moved in a most complicated fashion, so that not only does a little child take months to learn to walk, but when he first can walk, all his conscious attention has to be put into balancing on his feet and lifting them from the ground and placing them and adjusting his centre of gravity in such a way as to keep upright, and when he is doing this conscious control and conscious effort is taking place in the headquarters of

his central nervous organisation, which is concerned to such an extent that it has no attention over for other things. But after a few years when the art of walking has become quite easy through having been repeated so often, a boy may walk without realising the effort or even noticing the ground on which he walks. The oft-repeated delicacies of concerted balance having been gone through so frequently have become a routine of message and response, are now "short circuited" and accomplished without reference to the higher conscious centre. Hence many of our actions change in their relation to our nervous systems as we go through life, and movements which at first had to be learned with conscious effort and thought over may later on release the central consciousness from their consideration and manage themselves so to speak.

There are also extremely complicated and carefully interlocked and adjusted processes of vital importance in our lives, which never come under the control of our direct consciousness, or if they do so, come under that control when it is so undeveloped and youthful that we have as adults, no conscious memory of the time.

Breathing, an art acquired at the moment of birth with amazing adaptability is governed by a set of nerves which the grown man can never remember having to think about controlling in all his life, except for special moments. While our consciousness sleeps we breathe just as well as while it is awake.

The heart beats long before the infant is born, and its regular beat is controlled every moment of the day by

nerves, messages and impulses, over which an individual, in the ordinary way, has no control at all. At a moment of extreme stress, such for instance as a shock of anguish or sudden emotion, the perfect rhythm of the heart beat may receive a jar or jolt and create a nasty sensation of faintness, but it is merely a momentary jolt of the rhythmic beat, the control of which immediately slips back into the wonderful regular process which keeps us alive and which it is outside our consciousness. The control of functions like breathing and heart-beat over which most people have no conscious control, is said to be the "sympathetic system."

**Part of the spine, showing the entry and exit of nerves.**

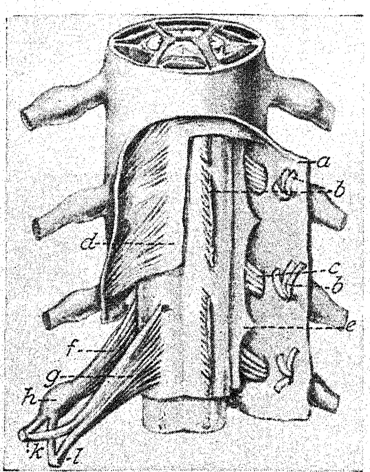



FIG. 43.

*a* *Dura mater*
*b* *Anterior nerve root* (*cut*)
*c* *Posterior nerve root*
*d* *Arachnoid*
*e* *Denticulatum*
*f* *Posterior nerve root*
*g* *Anterior nerve root*
*h* *Spinal ganglion*
*k* *Anterior ramus of nerve*
*l* *Posterior ramus of nerve*

The different regions of the body, and the different organs inside the body cavity possess systems of nerves which are placed in definite positions, and which come off as branches from the central spinal column in a given order. Their

position is so regular that, for instance, a skilful masseur can lay his finger on the sensitive nerve dealing with any particular organ he desires to stimulate, and by massage and touch can stimulate that nerve in such a way that he may affect an organ in another part of the body. This power depends on knowing just where lie the exits and entrances of the various main trunks of the nervous system as they enter and leave the bones of the spine.

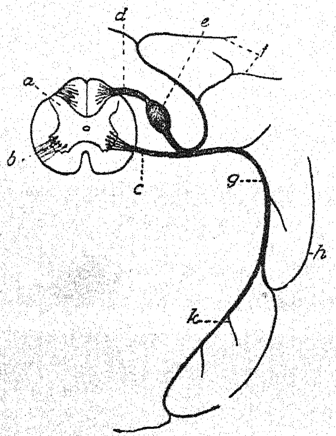



FIG. 44

*a* *Posterior grey column of spinal matter.*
*b* *Anterior grey column of spinal matter.*
*c* *Anterior root.*
*d* *Posterior root with ganglon.*
*e* *Ganglon.*
*f* *Lateral branches of posterior nerve.*
*g* *Anterior nerve.*
*h* *Branches in skin.*
*k* *Branches to muscles.*

The way the nerve strands are attached and are led away again from the spinal column is seen in diagram, fig. 43, page 161, where the anterior and posterior strands of the nerves and the spinal ganglion are seen associated with a part of the spinal column. An even simpler diagram showing this method of arrangement is seen in the cross-section, fig. 44.

From the diagram, fig. 51, page 204, you will see that the main cord of important nerves inside the spine begins at the solid bones terminating the spine, at the base of the skull. At the other end they taper and end blindly

in the column at the base of the pelvis. Along this region equally balanced pairs of nerves come off from the trunk through each spinal bone. The lower ones form very thick main trunks branching and dividing and going into the legs, the ones around the waist going to the various internal organs, the distribution and destination of which is symmetrical on either side of the spine.

Very large and important nerves again supply the arms, and then into the neck the spinal column is continued until the bones of the backbone join the skull and hand the precious nerve cord over to the protection of the bony cavity of the skull where the mass of the spinal column ends in an enlarged portion at the base of the brain. Connected on with this and differing from it in structure and appearance are the various parts of the brain. The lobes of the brain together make a mass that is in some ways like the inner double part of a walnut; that is to say they are all joined together in one definite organ, but are deeply crinkled and corrugated and cleft into lobes equal on either side. From the central higher brain, the important nerves are given off through holes in the skull to the eyes, ears, nose and various parts of the head.

Accident and sometimes the definite necessity of a surgical operation, has made it clear that the nerves from different zones of the spine, although controlling to a certain extent the local behaviour of the organs which they innervate, do not complete the consciousness of the central organisation. For instance, a man may break his backbone, and injure or sever the spinal column and thus

lose all the power of moving his legs himself, (for the nerve connection having been severed no conscious control can any longer be exerted) but he may at times imagine that he feels his legs, or feels pain in them, because his conscious brain knows that he still has legs, and remembers the kind of sensations which they felt. And sometimes even when they are cut off he may still *feel* them, because the torn or severed ends of the nerves feel some stimuli and carry the message up to the brain, and the brain there translates the message into having come from the part it normally should. At the same time if covered over with a blanket, an observer could stimulate with an electric shock and even pinch and tickle his feet, and the legs would respond to this stimulus, looking to an outsider as though he were feeling it and responding to the stimulus by kicking, and trying to shake it off. Such movement, however, would have no real power, and would depend entirely on the message carried by the stimulated nerve in the foot up through the leg, and movement would depend on the response coming straight down from the special centre not having connection with the higher brain, the man not being aware that his leg was moving.

On the other hand, a man whose central consciousness has been destroyed, either by a blow the effect of which is temporary, or by some disease or accident which destroys his intelligence, making him either insane or unconscious, may live on for a long time if his vital bodily functions are in good working order. He may breathe; his heart will beat; and he may even be able to digest food which

is placed within his body; his liver, bowels and all the internal organs will act in a more or less normal way; and bodily life will be carried on because the innumerable cells forming his tissues receive blood and oxygen which supply them with their food and warmth as usual. Although the body of such an unconscious man may be from the human point of view quite useless, lying on a bed, requiring care and attention and not able to control itself sufficiently to eat, nevertheless the innumerable cell communities of which it is composed are not affected by this to any great extent (at any rate at first) and they continue to carry on their individual lives in a normal fashion.

Hence we see that there are not less than two degrees of life-capacity within our bodies. One the degree of purely animal life which, depending on the inter-action of the communities of cells, marvellously complicated and richly beautiful in plan and design, working in complete unison gives a machine which is useless unless it is controlled by the higher consciousness and will lead nowhere and will accomplish nothing by itself.

Yet there is one more function which the organs of the body can themselves accomplish without the conscious knowledge and control of the higher brain. This function is comparable with one that is found in all the primitive animals and plants. It is, in many ways, the most remarkable bodily function which can be exercised, and it is the power of reproduction dealt with in the next chapter.

## CHAPTER XVII.

### *Reproduction.*

ANYONE reading this book may think it illogical, or surprising, that after considering the nervous system in the last chapter, I do not go on at once to explain the relation and the parts of the higher centres of nervous organisation, those in the brain consciously controlling man's activities. I am deferring this to a later chapter where its consideration seems to me logical for the following reason :—That without the power of really understanding the complexities and responsibilities of the higher social life of human beings, there is another bodily function which the independent organs may perform, and which completes the bodily cycle on a purely physical basis. This is the function of the sex life of two individuals, of the two differing and opposite sexes, the exercise of which results in the production, ultimately, of other individuals like their parents even although this be an unexpected or unforeseen result.

When I use the phrase an "unforeseen result" I use it in comparison with the production of young on the part of the lower animals. A rabbit, for instance, joins its mate, and some weeks later bears a brood of baby rabbits. The animal does not, and cannot, connect the two ideas, nor can it plan for the production of baby

rabbits with any idea in its mind that the community of rabbits needs citizens of any particular sort. The same applies to dogs or horses or cattle. But with them man's conscious need for beef and milk comes in, and he to some extent supervises and controls the relation between the act of sex and the fruits of it in the production of calves. Still there is no exercise of the consciousness on the part of the cow and the bull. Although they have brains they are small ones, incapable of realising all the complex life and all the subtle actions and reactions which are characteristic of the higher brains of the intelligent members of the human family.

Hence it is logical, now that we have completed the consideration of the physical body of the human being, to consider its power to reproduce before considering its higher brain. As is illustrated by some unfortunate cases in our own community, the exercise of the sex functions can be independent of any recognition of the social aspects of such powers.

It is seldom, of course, that human reproduction takes place without the exercise of some deliberate will from the higher centres of control in the brain, although it is physically possible that this could occur. Human reproduction, involving the co-operation with the Divine in creating a new human being, should always, and generally does, involve a deliberate and conscious choice of its great responsibilities. Yet, as we are considering the physical structure of our bodies, we must consider the fact that it is physically possible for the vital cells in the reproductive system to complete the cycle of their

development independently of the exercise of the conscious brain. Illustrations of this are found in our community when an unfortunate feeble-minded or insane person without adult intelligence has an active reproductive system. Such a woman may produce a baby which is, to all outward appearances quite as perfect as any other baby: its defects reveal themselves later when its intelligence should come into play.

Although this is most deplorable from the point of view of society, physiologically it is not at all surprising, for it is based on the fact that all the unit cells composing our bodily organs, will, if supplied with a sufficiency of food in the blood and lymph systems, and of oxygen and the other requirements of their kind, all carry on their own lives and perform their own functions independently of the consciousness of the higher unit, the human being. This applies to the reproductive cells just as much as it does to the cells of the heart, the liver, or any other system.

We see, therefore, that the complete human animal can, without any consciousness of its importance, exercise the function of its sex. When we think of the serious responsibilities, and of all the unique importance of human life, we realise that it is very deplorable that sex life should be exercised without a sense of responsibility. Hence, it is important to understand it as fully as possible so that its powers shall not be misused or injured through ignorance.

The essence of sex life lies in a very subtle internal difference, visible only when the minute individual sex cells can be seen under the microscope. These are of

two kinds, the one is the egg or ovum which lies passively awaiting the awakening touch which will stir it into life; and the other is the much more minute but actively swimming, sperm cell which travels eagerly towards the egg cell, hurling itself within it in order to unite with it, and act as a lighted match to the wick of a lamp. The egg cell, although very large compared with the sperm cell, is also so small as to be invisible to the naked eye, yet it is for the production at regular intervals of these minute egg cells that all the characters in a girl or woman which make her different from a boy or a man exist. All the girl's femininity is made to serve in one way or another towards the great final object of the existence of the egg cells within her, namely, the production of new human beings through their division and growth.

Similarly on the part of a boy or a man, all the outer organs of sex which are visibly recognisable, and all the inner glands are there as accessories and in order to assist the organs in the production of sperm cells and the placing of them within the region where it is possible for them to find and unite with the egg cells of a woman.

Not only in man and woman, but in cow and bull, buck and doe rabbit, in fact in all the higher forms of life and in nearly all the insects and lower forms of life; indeed also in nearly all higher plants, and ultimately in most of the lowly and microscopic plants, there are two such differentiated sets of cells—the egg cells and the sperm cells. Sometimes these are sent out into the world as simple uncovered pieces of protoplasm. They may even be thrown out into the sea-water to find each other by

chance, as they are by fish and lowly plants. In all the higher organisms, however, of both plant and animal worlds, these cells are protected and surrounded by what may be described as a guard of ministers and attendants to serve them and make sure that they fulfil their special function. Naturally in human beings, who form the highest group of creatures in the world, complexity is to be expected in all the surroundings of the egg and sperm cell. The object of their existence, however, is in all life the same—the production of new individuals like the parents which will carry on the life of the species after the parents have served their purpose, have lived their span of life, and had to pass away through death, the fate which overtakes all specialised organisms.

A flower with its colour beauty and scent is the reproductive apparatus of the plant, made to surround and protect the egg cells and the sperm cells until they have united, then divided and grown to produce seeds. Then, as you know, when the winter comes and the plant dies down, the seed guards the life in the protected dormant condition, until next Spring, it is placed in the ground and will grow into a plant like its parents. The plant thus prepares for the long hard time of the winter. But animals, owing to their power to move about are less dependent on the seasons, and do not produce young which are packed away like the seeds prepared for a hard time. Higher animals on the contrary produce tender little creatures like kittens and puppies whimpering for the immediate warmth and protection of their mother's care, and the milk with which she can provide them until

they grow up capable of independent life away from her.

Nature has amazing ways, and sometimes we truthfully call her a cunning witch, for although it is her design and intention that the special aspects of sex life shall lead to the production of young, she does not too openly tell living creatures this, but cunningly makes the two sexes so attractive and pleasant to each other that, without any thought of the young which will result from their mating, they are attracted by each other for the length of time that is necessary to do the special work nature has designed them to do. The higher the animal is, however, the more important to its general social life, become all the accessory characters of sex. So the higher animals instead of remaining together for the brief period which is necessary to bring the egg cell and the sperm cell in contact, tend to pair faithfully together and link their lives not only long enough to rear the young which result, but they may remain faithful mates for the whole length of their lives. There is a species of wild duck, for instance, in Japan that refuses to mate with any other bird and dies of grief when its mate is killed.

In human beings the social aspects of the sex differences are of course far more important than in any animal's life, and this rising significance of the social aspects of sex and the differences between the two sexes blends with the increasing importance of sex in the whole physiology of the individual body.

We have, with very few exceptions, throughout this book spoken of all the important organs independently

of sex because there is very little or no difference between the vital organs of the two sexes. Both have two feet, two arms, heart, lungs, liver, digestive system, nervous system, almost identical—entirely identical in fundamental construction, and only varying a little here and there in size and colour, in relative weight and build, and then varying so little that the man and the woman have nearly all the ordinary attributes of human beings in common.

The two bodies, however, are differentiated in connection with their sex lives so that it is possible to recognise the male from the female even from birth, and this is largely due to the curious and (to me) hitherto always unexplained fact that the very important reservoirs of sex cells (or the sperm) are not protected inside the body as are the ovaries, but lie externally in the special sac or scrotum. These most delicate and precious receptacles one would have thought should have been protected carefully within the body wall as the corresponding organs, the ovaries, are protected in the body of the woman, and indeed in the early development of the young male, before birth, these organs are internal, but they take their place externally during the last months before birth.

Both the man and the woman also possess rudiments, (that is small and undeveloped structures) corresponding to the complete organs in each other's bodies, and this is particularly well seen in the breasts, where the woman has the full developed breast which can produce milk for her baby when it is required, whereas the man has only the small nipple without the milk producing glands,

though they are sufficiently well marked to show that they are an exact parallel of the breasts of the woman in spite of having remained rudimentary in the man.

The rudiments of each sex are found in both, and it is thought that the fact that these rudiments do not develop fully is due to the repressive action of some glands within the body which control the production of the glandular "hormones" or messengers.

The difference between the two sexes, however they are brought about, contribute vastly to the richness, complexity, interest and success of life. A normal human being instinctively wants, and should want, to be either a fully developed womanly woman or a fully developed manly man, and only when two such persons of differing character meet and link their lives in the normal sex life does the race stand its best chance of being carried into the future in a vital and healthy fashion.

It should be recognised by quite young people that the race is of immensely more importance than the individual, that is to say that however much pain and sacrifice an individual man or woman may be called upon to endure, it is of small account so long as the whole community of human beings is flourishing and carrying into the future all the potentialities of development which human beings of the best type may attain. Nevertheless, it should also be realised that the simple physiological laws of life are such that there is far more chance for normal, healthy individuals, who themselves are perfectly well and happy to carry on the race in a normal and happy fashion than those who are diseased, weak, or abnormal in any way.

But all these considerations which affect the community are outside the scope and beyond the control of the individual sex cells within the body. These sex cells, given an opportunity, that is to say given direct contact with each other, which leads to their fusion, will immediately start that immensely complicated process of union, followed by division and multiplication of their cells which initiates a new individual.

Mention has already been made of the chromosomes, (*ante* p. 103) in the cells producing the ovum and the spermatozoa the number is normal, but in anticipation of the *fusion* which would double the number, preparation for fertilisation includes the throwing off by each of half the usual number of chromosomes, so that when the two ripe sex cells meet and fuse the result is the normal number of chromosomes in the fusion-nucleus and all its descendants.

Once the egg cell with its nucleus and protoplasm, is surrounded by spermatozoa or male cells, (which are so small that they are just minute dots in comparison with the egg cell) the sperm swim actively in the local medium surrounding the egg cell till one of them penetrates the protoplasm of the egg. Then it throws off its own tail of protoplasm and its nucleus unites with the nucleus of the egg cell. After that the protoplasm changes its quality and protects itself from the entry of other spermatozoa, and then the nucleus which is made of the union of the male and the female, *i.e.*, the sperm and the egg nucleus, divides up with that wonderful karyokinetic process we have already described as taking place in the

simpler ordinary divisions of the tissue cells in the ordinary growing body, see *ante* page 103. The difference between the divisions resulting after the egg cell and the sperm have united is, however, very fundamental, because when an ordinary tissue cell divides, it produces only other tissue cells like itself, but when the nucleus that is made by the union of the male and female cell divides, it goes repeatedly through the karyokinetic process without specialising. These young cells form then a little ball or mass of soft unspecialised cells, called a morula. That is the beginning, the very earliest stage, of the embryo or the new life.

With the later stages of its development taking place within the woman's body, the male cell has nothing further to do. It has merged its life in the ovum. Hence we must recognise in the woman's body that two sets of organs are developed in connection with her sex, viz., those which correspond to those in the man and are accessory and used only in preparation for the bringing together of the male cell and the female cell in the sex act, and those which she alone has, and the man does not develop, which are accessory to and contributory to protecting and carrying the embryo, which remains in her body until it has grown sufficiently to be born.

Let us, therefore, now consider the structures specially characteristic, first of the man and then of the woman.

## CHAPTER XVIII.

### *The Body and the Race : The Male.*

IN human beings, from birth, there are some external differences between the two sexes. In babies the differences are less than between adults, and the little girl baby and the little boy baby are alike except that the boy has the small external organs which are generally spoken of as the male organs, and which are an *addition* to the various parts of the body visible in a girl baby.

So far as the outer eye can judge, even at birth, the boy's important sex organs are already present although they are not sufficiently developed until years later to do their racial work. Nevertheless the sex organs are already doing their work for the *individual*, and from the moment of birth, even preceding birth, the various glands and outer "accessory" structures of the sex organs are guiding and controlling the general development of the body.

In a man the sex organs lie together at the base of the trunk, (see fig. 1, p. 8) and most of the important organs and tissues concerned are all contained in a bag or sac of rather crinkled and elastic skin, which is called the *scrotum*. Within this the two organs of prime importance are the oval semen-producing bodies, each about the size of a pigeon's egg, each of which is called a *testis*, and together called the testes.

Each testis is not a uniformly solid mass of cells, but is divided up by ridges into compartments or cavities, which all communicate into one long tube common to them all, and in each of the compartments (which are well supplied with blood vessels and rich with nourishment) are the cells which divide and give rise to the actual sperm.

**Side and front view of human spermatozoa.**

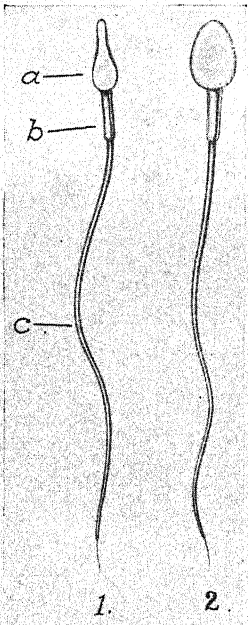


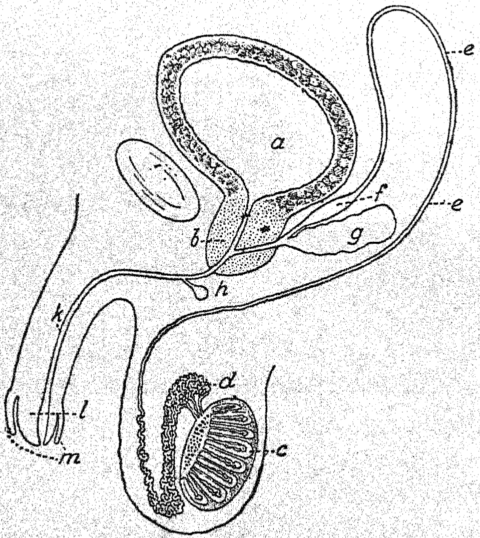

Fig. 45.
*Magnified* 1300 *times. Though only consisting of one single cell, its shape is specialised and the parts spoken of as—*
*a "Head." b "Body."*
*c "Tail."*

The *spermatozoa* or *sperm* are produced in immensely large numbers in each testis, several millions at first and ultimately hundreds of millions are present. Each consists of a single minute cell, with a long motile tail as described in a previous chapter, see fig. 45, and the nucleus of each is prepared for fusion by *halving* the number of chromosomes characteristic of ordinary tissue cells.

When the *sperm* (otherwise semen) are produced they travel from each cavity to the central channel, and then along a very much elongated and twisted channel, many feet in length which is coiled backwards and forwards on itself (rather like the way the intestines are coiled upon themselves) and this channel or canal is called

the *vas deferens* (*e*, fig. 46). It curves upwards and inwards towards the body from the hanging ball of the testis, and then turns suddenly down again and travels along till it joins the canal coming down the inside of the body from the bladder. Just about the place where these two

**Diagram showing the course of the canals for the testes and the bladder, their junction and the associated glands.**




*a* *Bladder*
*b* *Prostate or prostatic gland*
*c* *Testis*
*d* *Epididymis*
*e* *Vas deferens*
*f* *Ampulla*
*g* *Seminal vesicle*
*h* *Cowper's gland*
*k* *Urethra*
*l* *Glans penis*
*m* *Prepuce*

FIG. 46.

canals join is a side branch from the vas deferens which forms an enlarged chamber and is called the vesicle or *seminal vesicle* (*g*, fig. 46), because it forms a kind of room or storehouse where the sperms are stored up after they are produced. This lies at the point of juncture of

the canal from the bladder, and the vas deferens. Here also is a gland which is called the prostate gland, which is very important as it secretes a substance which is specially valuable, partly from its internal effects on the whole system, and partly because it has a tonic and vitalising effect on the stored spermatozoa so that when they come in contact with the prostatic secretion, they become highly active and are thus able to play their part and swim strongly when they are released in the right place.

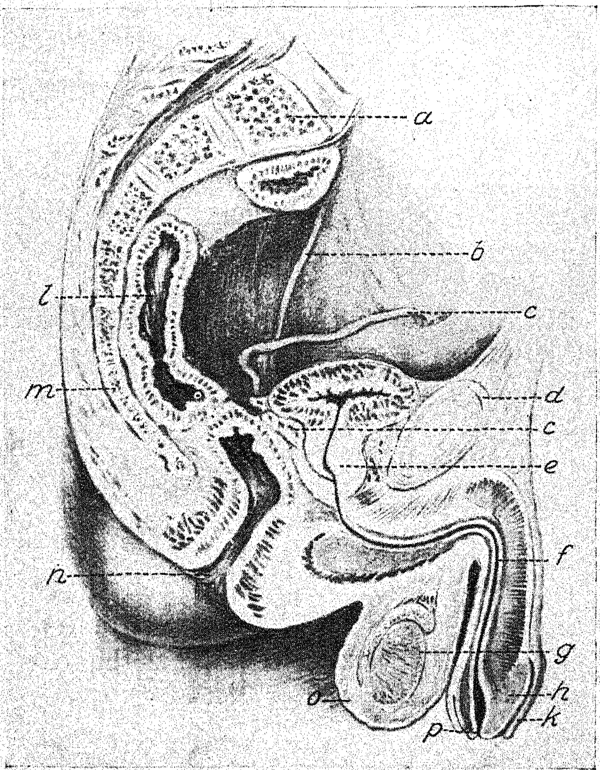
A little further down is Cowper's gland, another of the glands which add important secretions to the seminal fluid. The canal from the testes and the canal from the bladder join, and the *urethra* proper therefore forms a passage way for the products of the two distinct systems, both of which travel along the penis to find their exit. (See figs. 46 and 47).

The channel or canal of the urethra might be compared roughly to a roadway, wide enough only to have tram lines for the use of trams, but along which motors also run, so that the two kinds of traffic that have to travel on the same road have to do so at different times. The urethra from the region where the *vas deferens* and the canal from the bladder join is sometimes used as the roadway for the sperms and the secretions of the sex glands, that is to say for the sex secretions, but at other times is used by the secretion from the bladder, which as you will remember, *ante* Chapter VIII, page 87, stores up the liquid prepared by the kidneys in their process of cleansing the blood.

The urethra runs through a very special organ, the

*penis*, which therefore has two quite distinct and differing duties to perform. The simpler duty and the one that is

**Longitudinal section through the basal part of a man's body showing the relation of the bones, sex organs, and bladder.**




*a* *Base of spine cut through*
*b* *Ureter*
*c* *Vas deferens*
*d* *Symphysis pubes*
*e* *Prostate*
*f* *Urethra*
*g* *Testicle*
*h* *Glans penis*
*k* *Prepuce*
*l* *Rectum*
*m* *Coccyx*
*n* *Anus*
*o* *Scrotum cut open*
*p* *Opening of urethral canal*

FIG. 47.

in more frequent use is that of carrying the liquid from the bladder away from the body, and for this purpose the

simple urethral canal, with its external opening at the tip of the penis suffices, and is, as every boy knows from personal experience, used at will, and with voluntary, that is conscious, control a number of times in every twenty-four hours.

The second, and for the race the much mor important function which this organ has to perform only comes into action when the individual is adult. It has then at suitable times to enter the body of a woman and to deposit there the spermatozoa and the secretions which come with them called the seminal fluid. This racial act should only take place at special times and at rather infrequent intervals. Yet on account of the vital importance of this duty to the race, the penis, even from the hour of birth is constructed so as to be specialised to perform this duty.

The main tissues of which the penis itself is composed contains an unusual number of large veins, and is therefore much more spongy in texture than most tissues in the body. The flow of blood through these veins is influenced and controlled by the sensations both of direct touch and also from the higher brain centres. When the racial act is in progress the blood in the veins accumulates so that the whole organ of the penis gets larger than it usually is, and becomes what is technically called "erect." Hence this tissue is called erectile tissue, and its use in connection with sex is that it temporarily strengthens the penis and thus enables it to guide and carry the seminal fluid into the right place.

The main length of the penis is covered by ordinary skin, but it has a very sensitive tip called the *glans* penis,

(*h*, fig. 47) which is covered by an extremely soft thin membrane which feels every touch most sensitively. In order to protect this, the outer stronger skin of the penis is elongated, and folds over it like the double fold of a lined bag. This is called the foreskin or *prepuce*, (*k*, fig. 47). Sometimes this extra length of terminal skin is longer than is necessary, and sometimes it may be a little too tight, and then it is advisable to have this skin cut away by a very simple little operation. This operation is called circumcision, and is always performed on Jewish baby boys for religious reasons. Some Christians are now adopting the habit because it is considered by some to be cleaner and healthier to cut away a fold of skin in which drops of liquid may lie and become a source of irritation unless carefully cleansed. I think it is wiser not thus to interfere with nature unless it is essential to do so.

Boys who have been circumcised are sometimes conscious of feeling and looking a little different in this part from the ordinary natural boy, and both they and their companions should know what has been done and the reason for it. It is well that they should also realise that the operation of circumcision does not alter the power of the sex organs or their capacity to fertilise, and generate children.

The tissues of the complicated sex apparatus in the male are exceptionally well supplied with nerves, some of which are controlled from the spinal centres in the waist region, in addition to the very sensitive nerves which send swift and intense messages to the central brain and higher consciousness from these

organs. As a result of the nervous messages and the feelings they have generated, the normal experience of the act of sex is an emotion giving very intense pleasure. The complex of feelings in the higher nerve centring round sex are of great importance and value to the community, for they encourage and invite man to use his sex functions in such a way as to carry on the race, just as the pleasure and enjoyment in food encourages man to eat and thus nourish and maintain his body.

During the time that this complex apparatus is developing in the boy and lad, there is the possibility of a certain amount of incomplete feeling. Sometimes the premature experience of this tempts them to play with the organs of sex, either in solitude or with each other, in ways which cannot give anything like the true sensations, and yet which are sufficiently pleasurable to become a temptation to those boys who are not well enough educated to understand that what they are doing is *harmful.* Such premature sensation is harmful both to their own development as individuals and still more harmful in its power to destroy the perfection of functions which they will require later on as married men. It is very important, therefore, that every boy (and girl too) should realise that all playing with or needless touch of the sex organs is detrimental. They should be scrupulously careful to avoid every unnecessary touch or excitement to these very precious and important parts of the body, because they are developing within them powers which are immensely valuable, not only to themselves when they will be grown up, not only to their wives or husbands

as the case may be, not only to their children, but to their country, which needs well-balanced strong men and women, and even perhaps the whole race, because the effect of a fine life or one of talent or genius may influence and lead the whole world.

To play with sex and to indulge in premature and partial enjoyment is like eating small, bullet-sized green apples instead of waiting for the ripe sweet fruit. The flavour is utterly different and the result is probably a fit of sickness, which if not fatal has bad effects. Perhaps this snatching at sex experience may be more rightly compared to the act of a foolish person, who desiring a sweet scented rose hastily tears open the small green bud, only to find that there is no colour and no scent in the undeveloped leaves of the bud, for though the petals of the rose are folded within the bud, they have no size, colour nor scent until ripe and the natural time has come for them to open out into the sunlight.

One further point should be realised by lads and young men. Nature in preparing the semen with its valuable vital sperms and all the accessory secretions as the boy is approaching manhood, sometimes desires to get rid of some of the semen that has been produced before it is time for the man to exercise his full sex functions, and this leads to a simple ejaculation in sleep. This usually happens when his voice begins to break and he gets several other of the characters of a young man at the time which is called the onset of puberty. This sometimes frightens a boy if he does not know that it is nature's simple way of disposing of premature sperm. This should

not take place frequently, and in some quite healthy young men it never takes place at all, but it is a phenomenon which has often puzzled the young and sometimes needlessly frightened them and throws them into the arms of quacks and swindlers. It is well, therefore, to realise that sometimes the cells in the testes which are making spermatozoa, produce them in such a number that they travel without any outside stimulus down the *vas deferens* and escape automatically at the opening at the end of the urethra. Mentally no anxiety or interest should be aroused; nature is simply getting rid of developmental stages she does not require for racial purposes.

The immense richness and fragrance of the mental and spiritual sides of mature sex love take one beyond the regions of this simple text book of physiology and cannot be touched upon here further than to say that in their higher and most satisfying form, they can *only* be experienced by men and women who have sound healthy bodies in which the functions act normally and healthily as nature intended, and who have not, either by premature use, or by excesses and misuse, injured the subtle balance of all the nervous and delicate tissues concerned.

Those only are completely healthy and supremely happy who have a realisation not only of the marvels of the body and the privilege of an intimate sex life on highly civilised lines, but also have a realisation of the eternal significance of the wonderful creative power they possess in the use of the sex function. For it is profoundly true that God Himself can only create another man or woman through the use of the sex organs by a mated

couple of those human beings now upon the earth. And, therefore, in his sex organs every boy and man has a sacred racial trust and the potential power of a divine creation. The gutter has too long claimed the monopoly of spurious knowledge and obscene laughter about the sex organs and their details. Let every honest and instructed boy with a clean vocabulary and a knowledge of the truth play his part in cleansing our race of all the evils such foulness has bred.

## CHAPTER XIX.

*The Body and the Race: The Female.*

THE girl baby at birth, and all through her early childhood shows very little external difference from a baby boy except the absence of penis and testicles. The two small points of the breast in her babyhood are exactly like those of her little brother, but in the boy they remain throughout life in childhood's rudimentary form, and in the girl they develop later to exercise their special capacity. The baby girl at birth is equipped with all the vital sex organs, which in later life will enable her to play her complex part in the racial processes, some of which have been indicated in the previous chapter.

The first and most important of the sex organs of a woman are the small groups of cells which produce the egg cells. These are called the *ovaries,* and are two in number, just as the testes in the boy producing the sperm are two in number. Instead of being external and lying close together as they do in the scrotum of the boy, they lie deep within the body near the hip bones at the back in the waist line, and are separated several inches from each other. The tissues of the ovaries contain various intermediate cells just as do the testes, in addition to certain larger cells which divide slowly and at intervals throughout the girl's life as she goes through womanhood. These

give rise, not to large numbers of sperm cells as do the testes, but each to one (or sometimes two) egg cells at regular intervals. The egg cell, or ovum, is much larger than a sperm cell, and although a very much greater number is produced than can ever be actually used by the woman, nature is much more sparing in their pro-

**Diagram showing the ovaries and internal sex organs of a woman.**

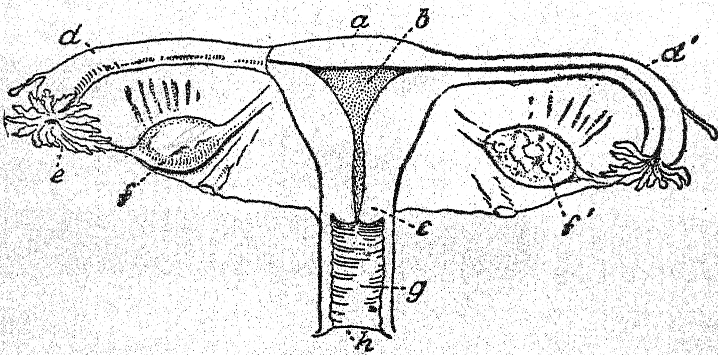



FIG. 48.

*a Fundus of uterus*
*b Cavity of body of uterus*
*c Cervix*
*d Fallopian tube*
*d' Fallopian tube (cut open)*
*e Fimbriated end of fallopian tube*
*f Ovary*
*f' Ovary (cut open)*
*g Vagina*
*h External opening of vaginal canal*

duction than she is in the enormously numerous sperms. The *ovum*, like the sperm cell, specially prepares its nucleus for fertilisation by throwing off half the ordinary number of chromosomes for the woman's sex organs, see figs. 48 and 49 and plate VI.

The *ovaries* are well supplied with blood vessels and nerves, and are attached to the muscular walls of the

body lining (*f*, fig. 48). Immediately above each ovary lies the funnel-like ends of the *Fallopian tubes*, which catch the ovum as it develops in one or the other ovary, (*d*, fig. 48), and then the ovum is slowly pushed along the Fallopian tube by the movement of the ciliated epethelium cells lining it (see description, p. 68 *ante*).

The two canals of the Fallopian tubes (*d*, fig. 49) open one on either side into the top of a strong central chamber which lies lower down and in the middle of the body, and which is popularly called the womb, and scientifically called the *uterus*, (*a*, fig. 48). This has a very thick muscular wall and is somewhat pear-shaped with the narrow end of the pear pointing downwards. The uterus has three openings, one on either side at the top into which the Fallopian tubes enter, and the central opening at the base, which is larger and which has very important circular muscles controlling it, and which is called the cervical canal, the neck being called the cervix—see fig. 48, *c*, page 188. This opens into the rather wide soft canal, (not represented at all in a man's body) called the *vagina* (*g*, fig. 48). The vaginal canal leads to the outside air, and while the girl is young and before marriage, it is nearly but not quite closed by a circular membrane which lies right across it and protects it from the entry of anything from the outside. Unfortunately germs are so tiny that it is not entirely germ-proof, and sometimes even young children get infective germs which penetrate through the small opening which is in this membrane.

The membrane closing the vagina varies a great deal,

**Longitudinal section through basal part of a female body.**

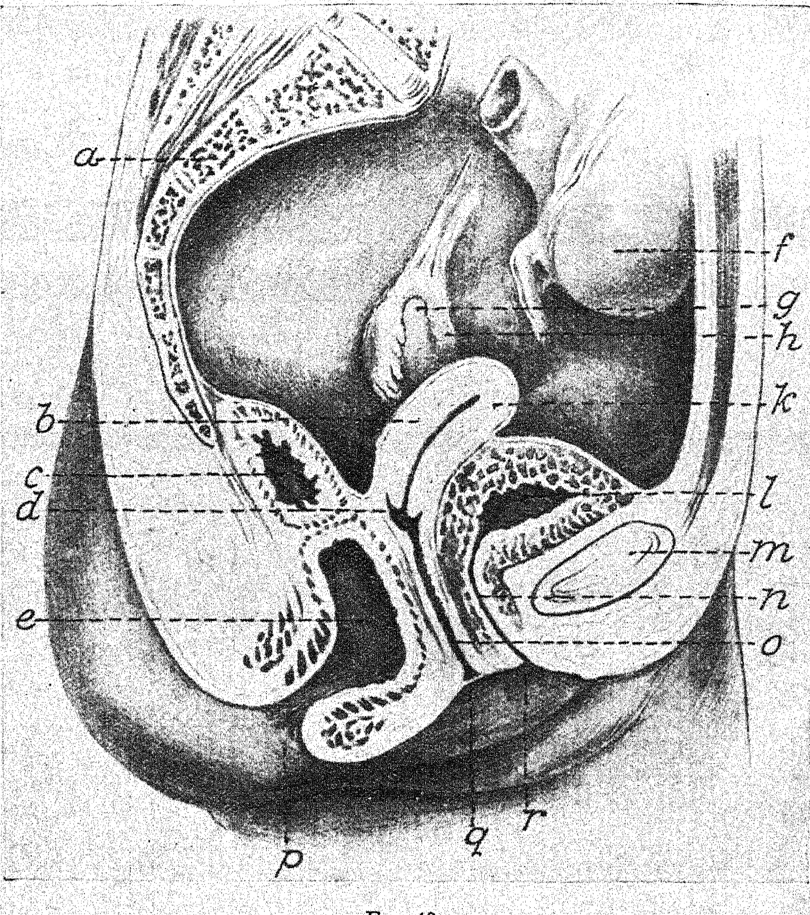



FIG. 49.

*a Section of spine b Thick muscular walls of uterus c End of intestines cut through d Cervix, or neck of uterus e Rectum f Caecum g Ovary h Fallopian tube k Uterus l Bladder cut through m Symphysis pubes n Urethra o Vagina p Opening of anus q Opening of uterus r Opening of bladder*

being much harder and stronger in some girls than in others, and so delicate in some that it breaks without their knowledge. As a rule it is a membrane which should be complete at the time of marriage and which should be broken only by the husband. This together with what was said in the previous chapter about the importance of the sex powers is in harmony with the social tradition that a girl, like her husband, should not have played with her sex organs before she takes upon herself the very serious and important joys and responsibilities of sex life in marriage.

Surrounding the inner and more important of a woman's sex organs are the two outer lips which close over the openings of the vagina and the urethra. In man, as we have already seen, the canal from the sex organs and the canal from the bladder unite into one tube, but this is not so in the woman, and the canal from the bladder and the canal from the womb have two separate and distinct openings, (see fig. 49). They lie very close together, and both are closed over by two sets of inner lips, a large pair and a small pair. The correct names for these are the outer and inner *labia.* At the angle where these lips meet is a very tiny organ, the *clitoris*, which is supposed to be an atrophied structure and which has no apparent function till after marriage.

A number of glands are also associated with the woman's sex organs, some of which stimulate and encourage the development of various feminine characteristics throughout her early developing life; others specially give out their secretion at the time of sex experience and then

assist in stimulating and encouraging the union of the sperm and egg cell. For instance, there are secreting glands round the neck of the cervix which give out a slightly alkaline fluid which assists the spermatozoa.

Just as in the organisation of the man, so in the woman, there is a very well developed and sensitive nerve supply to the sex organs, both the unconscious control which is correlated with and gives response to far lying organs in the body, and the central supply which at the right time and when mature conveys strong sensations to the conscious brain.

The sex life of the woman is by no means completed, however, with the acts of sex which she and the man unite to achieve. After that, within her body, many tissues have the much longer and equally important processes to go through which lead to the production of a living baby. These processes take place within the womb, but as the embryo there grows and develops, it influences and affects other parts of her system. Its history will be dealt with in Chapter XX, page 196.

Before leaving the individual life of the girl and woman, one further point should be mentioned. When she reaches the age of fourteen or so, the egg cells in the ovaries begin one by one to complete themselves and to escape. But at the same time at that early age the bones of her body and her muscles and tissues are not yet strong enough to bear the strain of motherhood, so that it is very important that she should not become a mother, although it is possible that she may be if she is permitted to make the great mistake of a premature use of her sex power. Though

she is protected from this as she should be both by knowledge (and therefore conscience on her own part) and by guardianship in the home, nature does not cease to ripen and set free one by one the ova from her ovaries at intervals of four weeks. At about the same time that these ripen each month, the inner surface of the uterus (the womb) naturally peels off and thus is cleansed in readiness and preparation for the important day when a fertilised ovum shall settle upon its surface and become an embryo. By that peeling off small surface blood capillaries are broken into, and a natural bleeding starts which lasts two or three to five days. This bleeding and the whole wonderful process of the preparation of the womb goes by the scientific name of *menstruation*. It generally takes place with almost clock-like regularity once every twenty-eight days (that is to say once every moon-month), though it is well known to vary a good deal in some women. This process of menstruation is natural, and should be like all other of nature's arrangements so simple to experience and live through that it should cause not the slighest pain or discomfort, even although some bleeding is involved. Unfortunately, owing to the unnatural life which so many girls lead, it is sometimes a period of minor suffering, but every young girl should understand that if things are *right* with her and as nature intended they should be, this time should neither cause her pain or inconvenience of any sort. Yet she should take a little more care of herself during these days, and it is particularly advisable that her brothers, and men with whom she may be working or playing should not over-

strain or tire her at that time by excessive dancing or tennis and so on. At that time the blood supply is somewhat out of the usual, and the womb is heavier and less able to support itself perfectly, so that if undue strain is placed upon it, the womb muscles may not be strong enough to withstand the strain, and the womb may get a little out of place, which may cause a girl a great deal of pain and discomfort, and may later injure her powers of motherhood. Similarly there is a greater liability than usual to catch a chill at such a time, but the common idea, alas too often spread even by the medical profession, that this is a time of sickness and inferiority is utterly false. You will generally find those women who have accomplished much in life are those who have been blessed with normal health, and consequently have not suffered at these important and oft-recurring periods in their lives. At the close of the menstrual period, and in some women several days or a week after it, the ripened ovum comes down the Fallopian tubes, passes through the womb and escapes.

Of all the diseases and the germs which can penetrate the sex organs both of the man and of the woman, there should be no more reason to speak than of the germs attacking any other organ, if it were not for the fact that until recently there has been so much false secrecy round our sex life.

Such germs, although much has now been done to prevent them spreading, are still sometimes innocently to be encountered in public lavatories, school and college, and hence however pure and clean a girl or boy may be

themselves, it is important for them to be on their guard against small drops of moisture which may lie on a towel or a wooden seat, and which quite unsuspectingly may penetrate and cause diseases which ruin the sex life, which otherwise should be so beautiful and valuable for them.

Let us hope, on the other hand, that the young man or woman have achieved the best and most important thing in life—a perfect and happy mating with each other; that they have accomplished the creative act which leads to the production of another life; and that within the potential mother's womb lies the tiny vital egg cell. Its development will be considered in the next chapter.

## CHAPTER XX.

*The Body and the Race: The Making of a Human Being.*

EVERY human life begins as a single cell, a soft mass of protoplasm with its central kernel or nucleus very similar to the fig. 17, on page 62, but although there are many cells, indeed there are myriads of cells in the body, only those originating as an *ovum* from the ovary can ever become a human being, even if placed under the proper conditions. Of all these cells in the ovary the only ones which can ever become human beings are those few which unite with a sperm cell in such a way that the sperm nucleus and the egg nucleus entirely mix and mingle as closely or more closely than water mingles with wine when stirred in a glass together.

The process of cell mingling is, of course, invisible to the naked eye, but it is not as completely without form as is the mingling of water with wine. Part of the extraordinary detail of this process can be seen through the microscope, and it is called the fusion of the chromosomes. The ovum and the sperm, you will recall, each have *half* the usual number of chromosomes, so that when the two fuse, the resulting cell has the usual number characteristic of the species, and thereafter retains that number through all its many divisions to produce tissue cells.

The way chromosomes elaborately dance when a nucleus divides has already been described, *ante* see page 64, because it takes place in every dividing cell in the whole body tissue, but the ovum, which when fertilised is the initial origin of the future embryo, differs from these ordinary body cells in the doubling and fusion with the chromosomes from the sperm before it divides. After that the process of karyokinesis, with the wonderful dances of the chromosomes along the spindles, take place just as was described for the body cells. Thereafter the two cells produced, instead of separating and each growing up to be like the parent tissue, remain together and again repeatedly divide. Each of these again divides until there is a ball or group of active unspecialised cells called a morula; which is the commencement of the *embryo.*

Very early in its history this little mass of cells, the embryo, attaches itself to the tissue lining the mother's womb. Then the cells by which it attaches itself act as a kind of sucker, which draw the necessary nourishment from the mother's blood system into the growing mass of cells of the embryo. Later as the embryo develops and produces cells which specialise to form its separate individual organs, the complex little creature lives within the womb in a pond of liquid supplied within its special covering membrane. Meanwhile all its nourishment, and the oxygen which it requires for the development of its cells are drawn from the mother's system.

Thus the mother carries in her womb the tiny baby which grows within her for 9 months. During most of this

time she is conscious that it is there, and during all this time she is making or marring its whole future life by the way she herself lives. Though at all times it is necessary to obey the physiological laws of our bodies, to eat wisely, to rest sufficiently and to care for our bodies, quite especially at this time it is obviously still more important to live rightly because every act which is done during this time affects the life of a developing creature and maybe affects it at a most critical time of its cell development.

The cells of the embryo are nourished from the mother's system, and the delicate embryo is provided with shelter, not only by the strong muscular walls of the uterus, and within that by its own protecting membrane, but also has the extra safeguard from every jar and shock of the liquid in which it floats. The invisible embryo cells grow and divide with such wonderful speed that in so short a time as six weeks it has become as large as a grain of corn, and the tiny future baby has the rudiments of its four limbs, its head and back present in miniature.

Although the rate of growth of the individual cells is rapid, yet the total number of cells which have to be produced to make the body even of a small baby is so enormous that it takes a long while for the cell divisions to be sufficient, and as a rule nine full months elapse from the first division of the egg cell to the date when it is safe for the baby to be born.

When the time comes for birth, the baby, which has hitherto been living in the liquid chamber within its mother and getting oxygen for its cell activities dissolved

in her blood as it is not able to breathe the open air for itself, suddenly feels the summons of birth, and with great rapidity prepares to take in air when it reaches the outer world. It separates its membrane from the tissues of the mother and travels towards the outer air through the neck of the womb which enlarges and stretches to permit its head to pass. The baby's head is nearly as large as the hollow of the mother's bone in the pelvis, and, although the neck of the womb, all through the mother's life before his birth is very small, at the time of birth the muscles stretch and become sufficiently elastic to allow the head to pass through them. The canal of the vagina also stretches, and the baby, assisted by great muscular contractions on the part of the mother finds its own way out into the outer world, and it utters its first cry as the first gulp of air enters its lungs. One of the most wonderful things in the whole of physiology is that though for nine months the embryo has been growing in liquid and unable to breathe, yet directly the baby is born it gulps in a breath of air and never ceases to use its lungs until perhaps as an old man ninety years of age he breathes his last.

Even when it is born, the baby is very tender and helpless, several of its bones are only soft cartilage and have not become hardened with the calcareous matter which work-a-day bones should have in them to support them. Also, as we have already mentioned the new born baby's eyes have not the power to produce tears, it has no visible teeth, its nails are filmy and soft, and it cannot stand or walk or take care of itself in any way. Nor can it eat

ordinary food. But directly after its birth another change takes place in the mother's body, in her breasts, which for all the nine months she has been carrying the child were very nearly as they had previously been, although a little enlarged in size and showing more veins in preparation for the work they would have to do. After the birth the many glands and food-secreting cells inside the breasts begin to work, and there, ready for the new-born baby, is the special milk from its own mother, which is its best nourishment. It draws that milk for several months until it begins to grow its own teeth and to be able to eat crusts and biscuits and other food, and to mix that hard food with cow's milk and gradually to take the foods which a grown-up eats. In the ordinary way the milk is supplied by the mother's breast for seven, eight or nine months after the birth of the baby, so that one may very well say that the act of sex union in which the man and the woman equally take part affects the man for one day, and affects the woman for eighteen months.

It is no wonder then that so much more emphasis is laid on the sex life of the woman than on that of the man. Physiologically the father's body has a much lighter task than the mother's, so in a civilised community such as ours the parents live their lives together, and the constant influence of his thoughtful fatherhood is with a man's children, and should be with them all his life.

In addition to this social companionship, the influence of the father is for ever present in his children through the strange and subtle working of what we call *heredity*. Popularly we say of a child that it "takes after its father"

in this or that feature. When more carefully examined, it is found that features and qualities may run in families for generations. The well-nigh magical thing, which still passes all our comprehension, is that any feature the child may inherit from its father must have been contained in minute form or essence in the chromosomes of the tiny sperm which lost its identity and merged with the nucleus of the mother's ovum. Let us say the child has brown eyes from the father (the mother having blue eyes), yet though no eyes (because no tissue structure of any sort was in the sperm) were in the sperm, its chromosomes had within them some commanding power over eyes, not only to see that they were regularly and properly formed as the embryo tissues grew and the time came for the eyes to develop, but to see that the eyes were *brown*. And all in the one invisible small sperm resided hundreds and hundreds of other controlling qualities which contributed to the developing child's characteristics and together form what we call its *heredity*.

The child inherits equally the possibility of hereditary qualities from its father and from its mother, and according to the dominant nature, or otherwise, of the different characters it shows one character or another. Yet so intensely complex are the manifold possibilities in any one life that no-one can predict the likely qualities of a child beyond the general result that healthy parents are likely to have healthy children.

## CHAPTER XXI.

*The Bodily Unit and the Community : The Brain.*

THE soft and precious mass of the human brain is protected in a hard bony box or shell, called the skull, formed of several bones. See fig. 50. The human brain is much larger in proportion to the size of the body than is the brain of any other animal. It is actually larger than that of all other animals with the exception of the elephant and the whale. With this large brain are correlated the higher faculties of mankind which endow the human race with its unique place in the world. To unravel the relation between that within us that we feel to be us "ourselves," and its instrument the brain which we can touch after death, and lay our fingers on, and the cells of which we can study under the microscope, puzzles the world. Whatever may be the relation between "ourselves," and our brains, we are aware that either within, or within and around, the regions of specialised tissues which compose the brain, there resides or comes into activity all the swift and complex sensations and reactions which unite to form our human faculties.

The essence of brain activity is the capacity to receive simultaneously a large number of different and rapidly altering stimulations from the outer world ; to translate these swiftly and accurately into terms of things material

The brain of a tiny baby enters the world with very few of these convolutions, and as the child grows, the brain not only grows rapidly in size, but its corrugations and complexity increase. In a general way the results of the examinations of the brains of great men and women who have died show that those with brilliant intellectual capacity are those not necessarily with larger or heavy brains, but with brains corrugated by a large number of fissures and convolutions, for these increase the surface area of the grey tissue of the brain. The active cells, when seen together in large numbers look grey from the outside, and these are found all over the surface of the brain and are called the "grey matter."

The central part of the cerebrum consists of whitish fibrous cells, which connect up and carry messages to and from between the various parts of the brain and the sense organs, by which they are served. Looking at the brain from underneath, the various parts are seen in the diagram fig. 52, page 206.

In this diagram you will see how the enlarged bulb at the end of the spinal column, the medulla oblongata, rounds itself off in the central back portion of the base of the brain and gives off a series of nerves which run to various parts of the head and neck and arms.

The cerebellum is double-cleft almost into two completely divided halves, which are connected firmly by the part called the *pons*, which consists of message-carrying, fibrous intermediate tissue. Then come the lobes of the main cerebral hemisphere.

When looked at from below the *olfactory* bulbs of the

**The brain, looked at from below, with the cut ends of the principal nerves.**

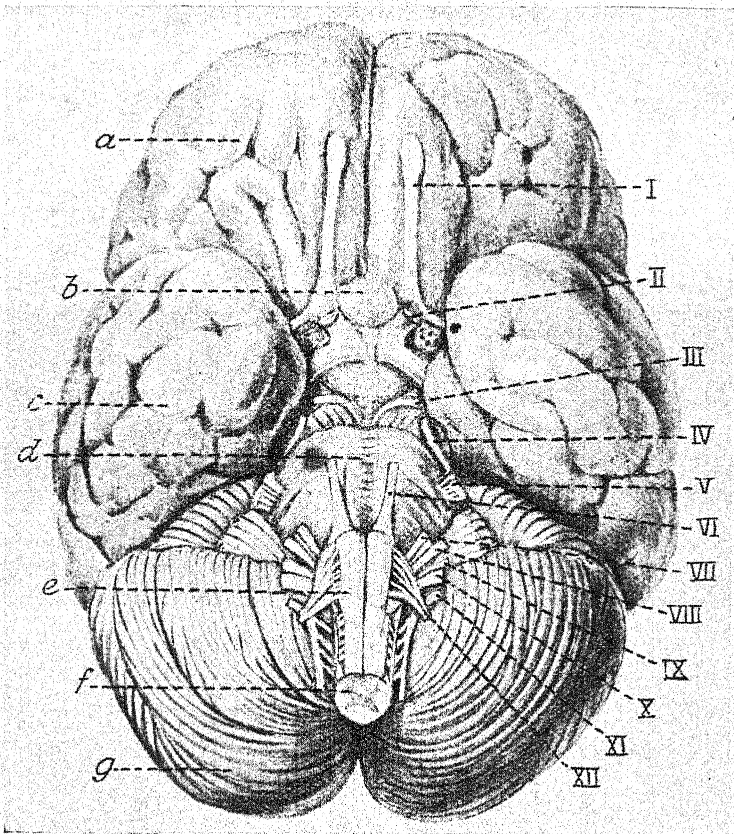



FIG. 52.

*a Frontal lobe*
*b Pituitary body*
*c Temporal lobe*
*d Pons*
*e Medulla obligata*
*f Medulla spinalis* (*cut*)
*g Cerebellum*
I *to* XII *Nerves* (see p. 208 in text)

brain stand out conspicuously as two elongated masses with club-like ends, and lying between them is a very interesting and significant little organ called the *pituitary*, (*b*, fig. 52). The pituitary plays a subtle part in the control and organisation of our bones and the shape of our bodies, but it is supposed long ago to have had quite a different *role*, and it is, therefore, what may be described as a *vestigial organ*, that is an organ which now no longer does what it used to do. When some time ago the term vestigial organ was given to such an organ as this, it was thought that it had no particular duties. But recent discoveries have taught us that where there lingers any organ apparently no longer playing its original part, it is usually adapted for something else, and the pituitary is one of the most important structures of the brain, for if anything goes wrong with the pituitary the very shape and sizes of the bones change, and with them the shape, the expression and the character of the man and woman may alter, until they are hardly recognisable as being the same individual.

As we noted when dealing with the senses of sight, hearing and smell (Chaps. XIII, XIV and XV), the special sense organs are very close to the brain, so that most of the nerves which are given off by the brain to them have not very far to run, and take a comparatively simple course through small holes or *foramina*, as they are called, which pierce the skull bones in order to allow the nerves to pass.

As may well be imagined in an organ of such complexity and importance, every small part, every nerve and blood

vessel, is named and described, but it is unnecessary to consider all these unless one wants to take up the study of human physiology or medicine, when the many detailed books on anatomy should be consulted. It is, however, worth knowing and remembering that all the important nerves come off in pairs, and that there are twelve principal pairs of nerves, the bases of which can be seen in the diagram, and which are numbered, each according to its number going to the following various organs and parts of the body : I give their correct names, but it is not necessary to remember them. The numbers are to be seen in the right hand of fig. 52 :

i. the olfactory nerve.
ii. the optic nerve.
iii, iv, vi. the nerves of the muscles of the eye.
v. the trigeminal nerve.
vii. the facial nerve.
viii. the auditory nerve.
ix. the glossopharyngeal.
x. the pneumogastric or vagus.
xi. the spinal accessory.
xii. the hypoglossal or motor nerve of the tongue.

Finally a word may be said about the significance of the shape of the skull and the brain capacity which it may or may not indicate. A semi-science has for long existed and attracted popular attention called phrenology, the practitioners of which claim that by feeling the bosses and indentations of a man's skull they can describe his character and attainments. This is an exaggerated claim,

but some truth in the idea is based on the fact that in the cerebrum, certain regions, although not in a very precise way, have been correlated with certain capacities in us. For instance in a rough diagrammatic form these regions

**The Brain, side view. General plan of the way various functions are localised in the cerebral cortex of the Brain.**

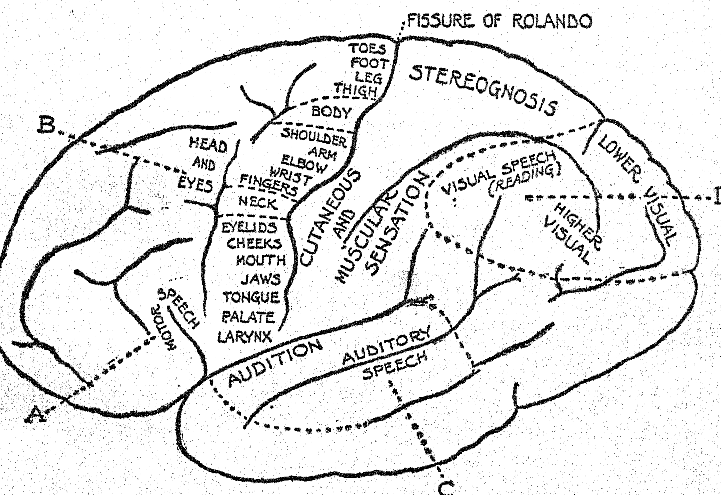



FIG. 53.

*a The centre of motor speech ; damage or decay here causes word-loss or aphasia*
*b Region controlling power of writing*
*c Region controlling the hearing of words*
*d Region controlling the visual recognition of words*

are indicated in fig. 53, and this brings out an interesting fact that such a capacity as speech, that is the power to think in words, to convey by words our impressions to another, and to understand and see and recognise these words when written down and also to listen

to the word sounds from another person are all controlled by different areas in the brain. These are indicated by the letters A, B, C, etc., in this diagram.

Thus it comes about that some local injury to the brain at region " A " fig. 53, may render a man incapable of speaking and thus appear to have lost his knowledge of words, but at the same time he may be able to *write* words quite clearly, whereas an accident to the area marked " B," would make it impossible for him to read words although he might be able to speak them quite correctly. These areas which are recognisable are called sense areas, and it is possible that when brains are more fully studied and understood than they are at present the various capacities we have may be all correlated within quite narrow limits into their own definite regions.

The tissues composing the brain consist like every other tissue in the body, of multitudes of minute cells. Those in the brain are specially delicate and sensitive, and have to be preserved even from such pressure as the liver or kidneys can endure without any inconvenience. Hence the brain tissues are all carefully adjusted and packed into the strong bony case of the skull. So easily are brain cells injured that if there is a slight swelling or pressure of a local blood vessel within the skull, then headaches and perhaps even unconsciousness may result. A blow or a fall on some of the sensitive areas, for instance, the side of the head and temple, may result in unconsciousness or even instantaneous death.

The brain is double-lobed in two halves and has what is called bi-lateral symmetry, that is the two halves are

very much alike. The right and left half have a corresponding arrangement of lobes, fissures and nerves, but it is found in modern civilised man that the blood supply somewhat differs in the right and left half of the brain, and the different arrangement of the blood vessels leaves its mark even on the hard casing of the inner side of the skull. The difference in blood supply appears to be correlated with our right and left-handedness and the general differentiation of capacity resulting from our habits. Speaking generally (although this is not strictly accurate) the right hand lobes of the brain control the left hand side of the body and *vice versa*.

Those who study the skulls of ancient savages and some of the primitive races do not find this differentiation of the blood vessels on either side, and it is probable that primitive man did not acquire a right and left hand capacity as we do. By the saving involved in the specialisation of our two hands this habit releases a certain amount of conscious capacity which can be put to other uses.

It used to be said that every cell in the body was replaced every seven years, but this is no longer held to be true. Whether or not some of the brain cells remain permanently on duty throughout the conscious lifetime of the individual is not finally established, but it is generally thought that most of our important cells do remain in active service for very much longer than the old-fashioned allotted span of seven years. Whether any one particular cell itself carries on for our lifetime, or whether as is the habit of most tissue cells in the body,

it dies after being worn out and is replaced by some fresh living cell that is generated in its neighbourhood and takes on its duties, the fact remains that the brain has a marvellous capacity to retain sensations which it has once received. From this arises the very curious, and even surprising power, which the brains of almost everyone possess, although it may be seldom used, of remembering more or less permanently even minute sensations which our "higher consciousness" has "forgotten." Sensations and visual pictures or words which have once been grasped by the brain may be relegated to what we are now getting into the habit of calling the sub-conscious. That is to say they form a background for our conscious thought, though they are not called into play. But under the stress of some intense emotion, or on the other hand under the influence of hypnotic suggestion or in some other way which departs somewhat from the ordinary routine of daily life, the sub-conscious will bring back into the consciousness of the individual events and ideas which may have lain dormant in the brain cells, apparently entirely forgotten, for half a century or more.

Our brains then are indeed most wonderful instruments, and a lifetime devoted to unravelling their capacities and learning more about them would be well spent, but it certainly would not be sufficient fully to understand them.

## CHAPTER XXII.

*The Bodily Unit and the Community: The Intellect in Command.*

ALTHOUGH no-one in the world can yet fully explain the marvellous mechanism of control and counter-control throughout the organisation of our bodies, nor reproduce any of the finer subtleties which the individual spirit of man inhabiting the body can employ so swiftly to meet the material conditions of life, yet science is daily adding to our knowledge of some of the intricacies of this mechanism. Many points are known which are of curious interest or of value for us to note.

One point which is amazing to the thoughtful student and is not yet fully recognised by many, is that by interference with the ordinary simple working routine of some of the functions of the body it can be detected how much *emergency power*, as one may call it, the consciousness has over organs, which, as a rule, it leaves to manage themselves.

Let us take for example the movements of the stomach in digestion and the secretions of the various glands which lie along the digestive tract, which are poured into it in order to assist the digestion of the food. In the ordinary way the movements of the stomach (see *ante* page 75) are not controllable by the consciousness, nor

directly affected by the thoughts in the higher brain, nor is the supply of digestive juices controllable at will. A series of very interesting experiments was carried out by Cannon and his colleagues who found that, for instance, if an animal is very frightened the message of fear from the brain paralyses the digestive muscles to such an extent that the peristaltic movements of the stomach cease and the digestive juices are affected, and on the other hand certain other secretions are poured into the blood. This was tested for instance on cats. When they are frightened by being put into a cage or tied up so as to hear a dog bark close to them, the effects of the fear are found to be transmitted to the digestive and glandular organs, and the chemical alteration in the juices has been measured.

Similarly with mankind, physical fear has a comparable effect. But more than that, mental *ideas* have similar effects, and if a man who has just eaten a hearty dinner with a good appetite is suddenly told " your wife and children have been murdered," the mental effect may be such that this grief and terror is transmitted directly to the stomach and the accessory glands. If the words " your wife and kittens have been murdered " were said to a cat, that would of course have no effect. In the man's brain the simple gentle sounds of spoken words can detonate with such intense mental effect because of the moral and emotional ideas which they convey. By such ideas man is distinguished from all other creatures.

Emotions can be induced in the human being from the

environment surrounding him ; but man has in addition the capacity to create within himself through his extraordinary powers of memory and also through his power of seeing in his mind's eye or visualising in his imagination events which have actually happened in the past, or fantastic dreams of what might happen, and such purely mental stimuli can profoundly affect the physiology of his whole body. He can at will reduce himself to tears or exalt and elevate his mind into a state of ardent joyousness. The limits of the capacity to do this are, of course, set to some extent by the physical conditions of the man or woman at the time. Thus one who is suffering from acute toothache and the sleeplessness it has induced will find it much harder to create pictures of mental peace and glowing joy in the mind than one who is well and comfortably fed and reclining at ease on a sunny bank. But however achieved, joy, peace and mental exhilaration have stimulating and health-giving effects, as fear and anxiety have depressing and paralysing effects.

Experiment has shown in many instances comparable with the one just quoted about the effect of fear on the digestive system that actual secretions are directly correlated with emotions, so it can be readily realised that by an exertion of the will, a considerable effect can be achieved on the whole physique of the body. There is a profound truth behind the popular teaching that "care killed the cat," and the converse which has become so popular to-day in the phraseology of Mons. Coué that if we concentrate on the idea that every day and in every

way we are better and better, we probably will become calmer, healthier and better than if we worried.

A generation ago physical science dogmatised more boldly than it dares to do to-day and knew less of the subtleties of the interplay of the internal secretions and the control of the mind over them, and narrow and dogmatic ideas were disseminated in the name of Science. To-day, while the true scientific spirit of enquiry and careful sifting of actual facts is rapidly spreading and increasing in its purpose and intensity yet the extent of the subtleties and complex inter-relation of all the parts of the human being are becoming so much more recognised that the true scientist to-day would be wary indeed of setting limits to the powers which may be exerted by the will of man. Revolutionary discoveries have been made in this century, and it was only so recently as 1911 that Professor Starling read his great Croonian lecture on the *Hormones*. These are *internal secretions*, the invisible messengers transmitted through the blood (and probably lymph) from ductless glands, and from several, probably all organs to outlying parts of the body, and thus controlling and correlating life activities in isolated organs. Since his first discoveries on these lines a monument of scientific work and observation has added to such knowledge. To-day all recognise not less than six or seven ductless glands of the greatest importance, mention of which is the commonplace of every advanced text book.

A recognition of the remote effects of the "hormones" has become so widely known as to be almost in danger of

receiving a lip service rather than a real understanding from the public at large.

In subtle ways, partly beyond and partly within his control are influenced and affected the multitudinous communities of cells dwelling in harmony within a man's body on which his capacities in relation to the world depend.

But the higher brain of man can also use and control the environment around him in a great variety of ways. He can take from the outside and place within the digestive tract of his body, so that it can penetrate and be absorbed through the cells into his system, substances of special and sometimes even of strong, almost magical, powers. Thus he can compound and use alcohol, and in this way may make himself drunk at will, and thus dull all the higher senses of control in his brain, reducing himself to a state of degradation and foolishness, or he can, using the same alcohol apply it to a sick man in risk of heart failure and restore that man to life and power by the controlled and moderated use of that same alcohol. Man can concoct from the poppy plant drugs which when taken deliberately and in a sufficient quantity can induce fantastic dreams and a numbing inertia and craving, or from the same drug he can apply a small quantity locally in such a way as to spare an invalid agonising pain or induce sleep in an over-wrought sufferer. What use we make of such external substances depends, therefore, not only on the capacities of the higher brain to prepare and understand their powers, but on something even higher than our intellect which we call *moral quality.*

Some consider this a spiritual quality, peculiar to the soul of the man who believes not only in the marvellousness but in the divinity of human life.

What we call civilisation is the control in myriads of ways of the utilisation of innumerable material things from the outer world so that they shall supplement, extend or enhance the lives of the communities of tissue cells within us. Many of the adaptations made in the last hundred years as a result of the discoveries by science of ways to use the material world have resulted in great extensions of our primitive powers. For instance, the quality in glass of yielding a translucent mass which we call a lens has been discovered by man to supplement the simple lens in his eyes and to magnify enormously the objects around him at which he desires to look. The large lens of the telescope focussed on the moon or the stars multiplies their apparent size to our eyes, and therefore brings detailed messages from them to our brains, which give us a much greater knowledge of their structure and appearance than the naked eye or the most far-seeing imagination of man could attain. And other lenses made of glass, combined in the microscope, and applied to things too minute for our eyes to perceive magnify them so that cells from our tissues, or the minute single-celled organisms living in water or floating in the air are so much magnified that they appear large enough for us to see their structure as though they were before us 300 or more times greater than their actual size, so that we can see detail in cell life which is to us invisible in nature.

In such ways, man's intellect has extended his range,

both into the minutely small and immensely large and with this extended range he has amplified his power of grasping and moulding the substances in the world for his own benefit. For instance the discoveries of microscopic forms of life which breed multitudinously rendered possible the great work of Pasteur. He and his many followers have helped humanity by finding out the relation of the lives of the minute creatures we call germs or bacteria and the derangements and dangers they cause when they penetrate and breed inside the body of man, and how they can be destroyed by chemical substances we call disinfectants before entering the body, and also by compounds and "anti-bodies" after they are within. By applying such knowledge, man can control to some extent the life of the many invading cells within his own body; he can assist his own scavenger cells in their fight with invading germs, and he can, carrying the war into the enemy's camp, destroy the death-giving germs before they enter.

All such knowledge has been freely harnessed to work for the improvement of conditions of human life. Whenever such a discovery is made, it is a further source of potential riches in the life of mankind. Yet there is a curious mental quality in the brains of many human beings (which perhaps may be traceable to what Walter Bagehot made so clear is a form of "herd instinct") and if any great scientific discovery is *very* novel, and suddenly places new powers within the range of humanity, people tend to organise an opposition to it. Hence very often the prophet who brings new and enriching knowledge is

persecuted. A curious and important example of this within recent times is to be seen in the life of the great doctor, Sir James Simpson, who, when chloroform was discovered saw at once in it a source of protection for the wounded spirits of those who had to endure great physical pain, and he desired therefore to give chloroform, with its temporary safeguarding oblivion, to those who had to undergo terrible operations or such serious pain as is connected with childbirth. He was violently opposed by the clergy and many of the doctors and public men of his day, who proclaimed that God had intended humanity to endure this suffering and that it was impious and wicked to try to alleviate human agony in this way! His answer was dignified and beautiful and consisted in the words:—

> "I am sure you deeply regret and grieve with me that the interests of genuine religion should ever and anon be endangered and damaged by weak but well-meaning men believing and urging that this or that new improvement in medical knowledge, or in general science, is against the words or spirit of Scripture. We may always rest fully and perfectly assured that whatever is true in point of fact, or humane and merciful in point of practice, will find no condemnation in the Word of God."

and, of course, after the passage of a few years all agreed with him, and to-day chloroform, as one of the powers for good and soothing help is blessed by all. Sir James Simpson was very right in his realisation that it is impor-

tant to safeguard the sensitive spirit of mankind from needless pain, because it is not only the pain suffered at the moment of unendurable agony, but the after-effects of such shock may be far-reaching, and may have a destructive effect on the brain long after the pain and all memory of the pain has passed.

As Sir James Simpson fought for and won the application to human needs of the scientific knowledge of chloroform, so in their turn must the pioneers and leaders of almost every great advance fight for and win recognition of the value of their new discoveries and inventions. Now that the intellect in mankind is taking more and more the command, and will increasingly do so as mankind is educated on the simple, straight-forward lines of "truth-seeking" (which is the simple English for Science) so will it become impossible for obstruction to block the way of scientific knowledge when it comes to bring help to whatever phase of our lives it may be applied.

The old words of wisdom "Man know Thyself" apply to-day with a greater intensity and power than ever before, and the first step in enthroning the higher intellect in command as it should be is to acquire some knowledge of the intricate and marvellous communities which unite to form the delicate machinery of man's body. I hope the reading of this book will lead to a desire for further knowledge and a greater sense of wonder and reverence, each for herself, himself, and for the community at large.

# KEY

TO THE

# ATLAS OF THE HUMAN BODY.

## PLATE I.

1. *Sternomastoid m.*
2. *Trapezius m.*
3. *Omo-hyoid m.*
4. *Clavicle.*
5. *Coracoid process.*
6. *Deltoid m.* (*cut*).
7. *Pectoralis minor m.*
8. *Biceps m.* (*short head*).
9. *Serratus magnus m.*
10. *Rectus abdominis m.*
11. *Internal oblique m.*
12. *Gluteus medius m.*
13. *Sartorius m.*
14. *Tensor fascial femoris m.*
15. *Sartorius m.* (*showing through fascia lata*).
16. *External oblique m.*
17. *Origin of pectoralis major m.* (*sternal part*).
18. *Pectoralis major m.*
19. *Deltoid m.*

*m = muscle*

## PLATE II.

1. *7th cervical vertebra.*
2. *Clavicle.*
3. *Head of humerus.*
4. *Scapula.*
5. *Ribs*
6. *Sternum.*
7. *Liver.*
8. *Stomach.*
9. *Pancreas.*
10. *Transverse colon.*
11. *Descending colon.*
12. *Small intestine.*
13. *Anterior superior spine of ilium.*
14. *Urinary bladder.*
15. *Neck of femur.*
16. *Vermiform appendix.*
17. *Caecum.*
18. *Ascending colon.*

## PLATE III.

1. *Manubrium sterni.*
2. *Right lung.*
3. *Left lung.*
4. *Rib (cut).*
5. *Pleura covering pericardium.*
6. *Greater omentum.*
7. *Transverse colon.*
8. *Descending colon.*
9. *Mesentery.*
10. *Rectum.*
11. *Termination of ileum.*
12. *Coils of small intestine.*
13. *Jejunum.*

## PLATE IV.

1. *Thyroid gland (isthmus).*
2. *Trachea.*
3. *Subclavian artery.*
4. *Subclavian vein.*
5. *Axillary artery.*
6. *Axillary vein.*
7. *Arch of the aorta.*
8. *Left pulmonary artery.*
9. *Heart (right ventricle).*
10. *Rib (cut).*
11. *Spleen.*
12. *Pancreas.*
13. *Kidney (left).*
14. *Abdominal aorta.*
15. *Left Ureter.*
16. *Left common iliac artery.*
17. *Left common iliac vein.*
18. *Pelvic colon (cut).*
19. *Urinary bladder.*
20. *Femoral artery (left).*
21. *Great saphenous vein.*
22. *Kidney (right).*
23. *Inferior vena cava.*
24. *Diaphragm (under surface).*
25. *Diaphragm (cut edge).*
26. *Right pulmonary artery.*
27. *Superior vena cava.*
28. *Innominate artery and right innominate vein.*
29. *External jugular vein.*
30. *Internal jugular vein.*
31. *Common carotid artery.*

## PLATE V.

1. *Trachea.*
2. *Left lung.*
3. *Interventricular septum of heart.*
4. *Right lung.*
5. *Cut surface of right lung.*

## PLATE VI.

1. *Fallopian tube.*
2. *Ovary*
3. *Uterus (fundus).*
4 *Vagina.*